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# WORKMANSHIP STANDARDS MANUAL

## DEC STD 116

Digital Equipment Corporation

PETER SIMPSON

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TITLE: Workmanship Standards Manual

ABSTRACT: This document provides the criteria for craftsmanship to be utilized in manufacturing and maintaining Digital products.

*Because of the format of this manual, individual pages will not carry individual revision levels.

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## FOREWORD

This Workmanship Manual has been developed and issued to provide in one document the criteria for craftsmanship to be utilized in manufacturing and maintaining DIGITAL products.

The manual will be utilized as a training aid for new employees and as reference for all personnel who build and maintain DIGITAL products.

The sections have been developed to provide ready reference to all information pertaining to specific tasks to be performed.

This manual will be revised periodically to improve its usefulness and completeness. A questionnaire has been provided in the back of the manual for your comments.

The employees of DIGITAL are the primary influence in maintaining workmanship standards and the quality reputation of our Company. Special attention to the important details of our work is the key to quality workmanship.

Gene Mondani

Manager Central Quality Assurance

## INTRODUCTION

### *How to Use this Manual*

#### *Index*

On page v you will find the index to all sections in this manual. A thumb index is provided for quick access to the section you want.

#### *Section Table of Contents*

From the index you will locate the detailed table of contents for each section. Every section of this manual is self contained therefore eliminating the need to cross reference other sections. Each section contains the following:

(a) detailed table of contents

(b) the PURPOSE of the section

(c) statement on WORKMANSHIP

(d) DEFINITIONS as they pertain to the section

(e) pages on which are provided the ACCEPTABLE (PREFERRED), ACCEPTABLE (MINIMUM) and the UNACCEPTABLE criterion photographically presented

(f) DIGITAL Engineering Specification references for RETROFIT, REWORK and REPAIR procedures and in some instances other meaningful references are given.

# INDEX

TABLE OF CONTENTS

SECTION 1.0 – CABLE AND HARNESS

section 1.0 | title CABLE AND HARNESS

## PURPOSE

The purpose of this section (1.0) is to establish and provide photographic representation of the ACCEPTABLE (PREFERRED), ACCEPTABLE (MINIMUM) and UNACCEPTABLE quality levels as they apply to CABLE AND HARNESS. These requirements shall prevail when specific information does not appear on Engineering documentation. Engineering documentation may define specific quality requirements which take precedence over general workmanship standards.

## WORKMANSHIP

All details of workmanship shall be in accordance with high-grade industrial electrical wiring and equipment installation practices as reflected in the following standards.

## DEFINITIONS

*Braid*

A machine-woven covering applied over wire. Usually made of textile yarn or fine metallic wires. (See Shielding)

*Branch*

See "Breakout".

*Breakout*

The point at which a wire or group of wires emerge from a laced portion of a wire harness or cable assembly.

*Cable*

A transmission line, group of transmission lines or group of insulated conductors mechanically assembled in compact flexible form.

*Cable, Coaxial*

A transmission line in which one conductor is centered inside and insulated from a metal tube that serves as the second conductor. The insulation may be a continuous solid dielectric, or there may be dielectric spacers and an insulating gas. Also called coax, coaxial line, coaxial transmission line, concentric line and concentric transmission line.

*Cable, Shielded*

One or more insulated conductors covered with braided metallic outer conductor.

*Compression Crimping*

Compression crimping is a method for joining an electrical conductor (wire) to another current-carrying member. The compressed juncture is called the "crimp joint".

*Connector (Multicontact)*

Electrical connectors provide a means of rapid connect or disconnect of one or numerous circuits and/or extension of existing cable lengths. There are two types in the connector family; namely, plugs and receptacles.

a. Plug – Is not secured to any wall or panel but is free to move in order to be plugged into a receptacle. A plug may be either a male or female construction.

b. Receptacle – Also referred to as a "Jack" (single type) normally mounted to a surface. A receptacle may be either a male or female construction.

*Continuity Test*

An electrical test to determine the presence of a broken connection. The recommended instrument is the ohmmeter, not a buzzer. The buzzer function depends on the battery voltage which is in excess of the permissible tolerance for continuity test; usually the buzzer sounds above one ohm, which is not acceptable. In a continuity test, the goal is zero ohms.

*Fanout*

A fanout is a single or group of wires that break out from a trunk or branch to be terminated.

*Grommet*

A rubber extrusion, the primary use of which is to cover the sharp edges of a hole and prevent wire, cable, or harness damage.

*Harness*

A number of individual wires assembled into a cable, or series of branching cables, that will fit into a specific area.

*Lacing (Tie-Wrap, etc.)*

Lacing is the retaining of wires by grouping in a bundle or designated pattern and securing by various ways. Tie wrap is considered a form of lacing.

*Pigtail*

A short, flexible wire, usually stranded or braided, used between a stationary terminal and a terminal having a limited range of motion, as in relay armatures.

*Service Loop*

A small portion of wire or conductor which is added to the over-all length to facilitate maintenance and further serving.

*Shielding*

A metallic covering used to prevent magnetic or electrostatic coupling between adjacent circuits.

*Shielded Pair*

A twisted pair of conductors, over which a close copper braid has been applied.

*Spot Tie*

A tie made with cord to temporarily or permanently tie groups of wires together at one point.

*Strand*

One of the wires or group of wires, of any stranded conductor.

*Tie Wrap*

See Lacing.

*Tinning*

Tinning of lead wires is a process of applying a thin coating of solder to the surfaces of the stripped lead. Wires are tinned to bond the strands together to prevent fraying during handling and to preserve the solderability of the surface.

*Trunk*

The trunk is the main body of the harness.

*Twisted Pair*

A cable composed of two insulated conductors twisted together without a common covering. A twist being on complete turn (360°) of the individual wires.

*Wire Stripping*

The removal of the outside insulation. Three methods can be used: thermo stripper, mechanical handstripper, and automatic machine.

*Wiring Harness*

A wiring harness is the grouping of conductors terminating in permanent connection at either or both ends, usually completely within a chassis or subassembly.

*Wire/Lead Dress*

The arrangement of WIRES/LEADS in an orderly manner.

## WIRE

*General*

Wire shall conform to the applicable drawing specifications and shall be capable of being stripped clean by means of insulation strippers. All wire shall readily accept tinning and soldering.

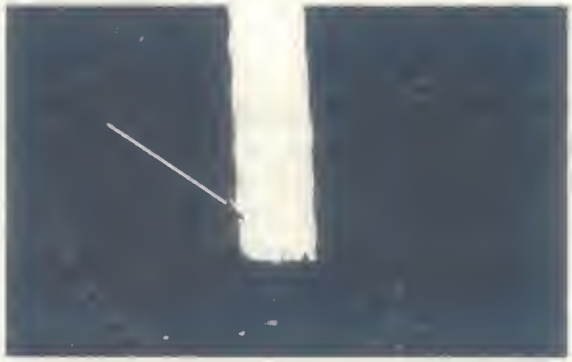
*Stripping*

The insulation must be removed from the ends of wires to permit soldering or mechanical attachment of terminals.

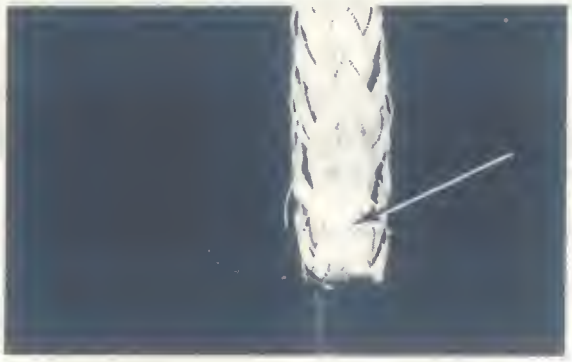
*Outer Jacket*

The outer jacket of shielded, coaxial, or multi-conductor cables, must be free of cuts, nicks, or scrapes of the shield braid or conductors as specified in Table 1.1 (on page 1-6)

ACCEPTABLE (Preferred)
Shield insulation stripped with no broken or scraped strands.



ACCEPTABLE (Minimum)
Slight fraying of jacket and maximum allowable damage to the shield braid.



UNACCEPTABLE
Extensive damage to the shield braid.

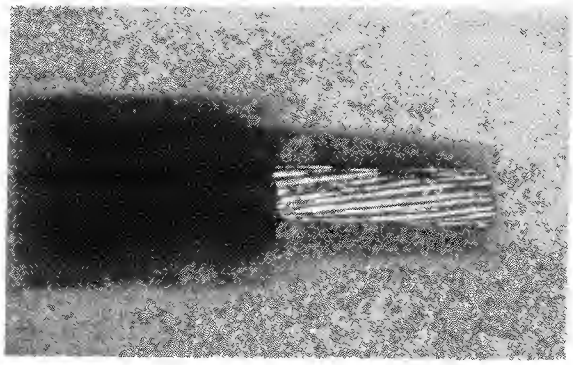
## WIRE (CENTER CONDUCTOR)

*General*

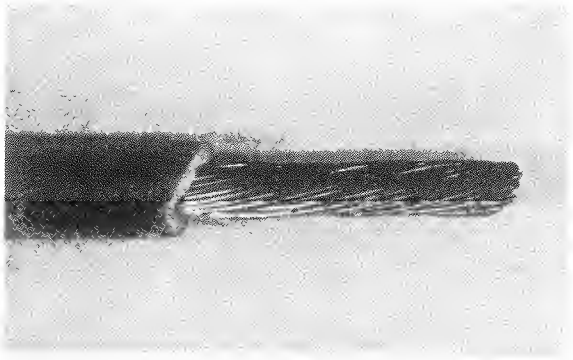
The trimmed edge of the insulation on stripped wires should be neat, smooth and uniform. The insulation must be complete and intact with no cuts, burns, or tears.

Flat spots (compressed insulation) are not acceptable if the wire strands are visible through the insulation. The number of damaged or severed strands in a single lead shall not exceed the limits in Table 1.1. (on page 1-6)

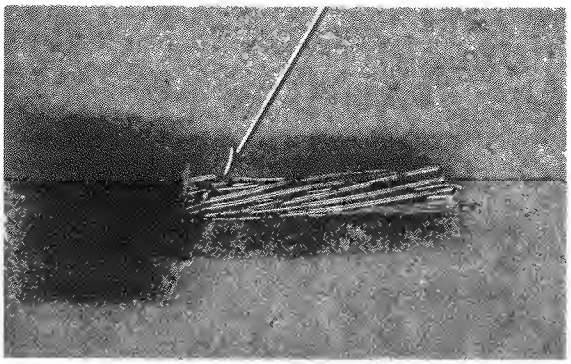
*NOTE:* AC power cords, power supply or any other high voltage circuit wiring shall have no broken strands or damaged insulation.



ACCEPTABLE (Preferred)
Stripped wire with smooth cut insulation and no scraped, cut or broken wire strands.



ACCEPTABLE (Minimum)
Fraying of the insulation, with a minimum of damage to the conductor.



UNACCEPTABLE
Slight fraying of the insulation but extensive damage to the conductor.

*Minor Scrapes*

Minor scrapes shall be defined as the removal of plating or copper from strands in a longitudinal direction, which removes less than 25 percent of the cross section of the strand. Minor scrapes are permissible on ten percent, maximum, of the strands.

*General Acceptance Criteria*

The following are characteristics of the acceptable stripped insulation:

(a) Trimmed edge of insulation neat, smooth, and uniform.

(b) Shielded, coaxial, and multi-conductor cable jacket stripped clean.

(c) Stripped area of coated insulation clean and bright over the entire exposed area.

TABLE 1.1

| STRANDS IN CONDUCTOR | PERMISSIBLE BROKEN/NICKED STRANDS |
|---|---|
| 0 – 6 | 0 |
| 7 – 16 | 1 |
| 17 – 26 | 2 |
| 27 – 36 | 3 |
| 37 – 46 | 4 |
| 47 and up | 10% of Total |
| | |
| Shield Strand only | maximum 10% broken/nicked strands |

*General UNACCEPTABLE Criteria*

Evidence of any of the following conditions shall be cause to consider the stripped wire UNACCEPTABLE:

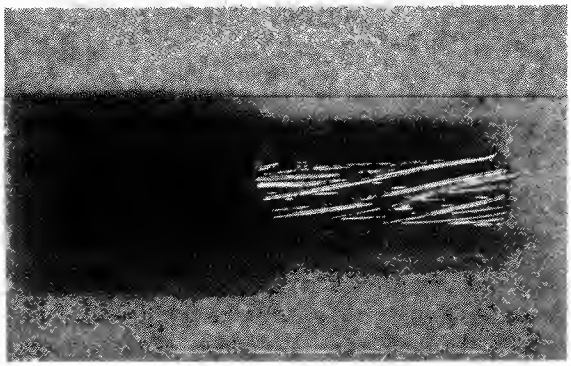
(a) Wire with torn, nicked, deformed, crushed, burred, burnt, splintered, or cut insulation that exposes wire.

(b) Wire with broken, nicked, scraped, stretched, or cut strands exceeding Table 1.1. (on page 1-6)

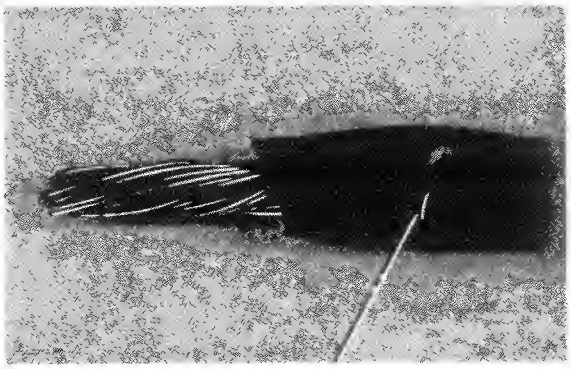
(c) Wire stripped with more than 15 degrees from perpendicularity of the wire.

(d) Cut braid strands exceeding Table 1.1. (on page 1-6)

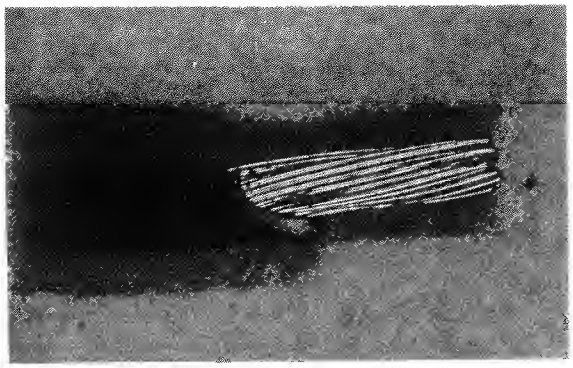
(e) Broken wires on high voltage circuits and AC power cords.



ACCEPTABLE (Minimum)
Insulation is crushed but does not expose the conductor. The conductor is slightly damaged.



UNACCEPTABLE
Damaged insulation where conductor is visible through the insulation.



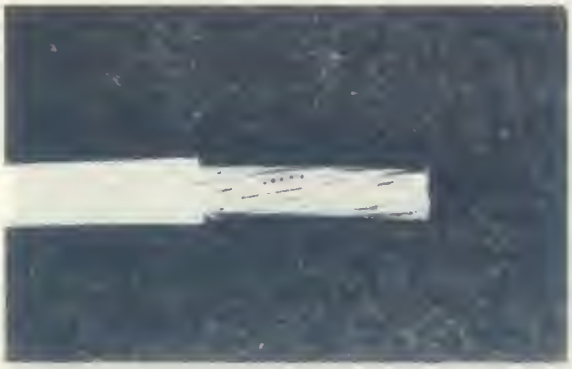
UNACCEPTABLE
Extreme angle of the insulation cut with slight damage to the conductor. Angle of cut is in excess of 15 degrees.

## TINNING

*General*

When tinning is specified, the same solder alloy shall be used for the pre-tinning as will be used in subsequent soldering operations. Solder should be kept to a minimum and should not obscure the outline of the strands.

When full tinning is specified, the entire stripped end of the wire is tinned to within approximately 1/16 (0.062) inch from the insulation.



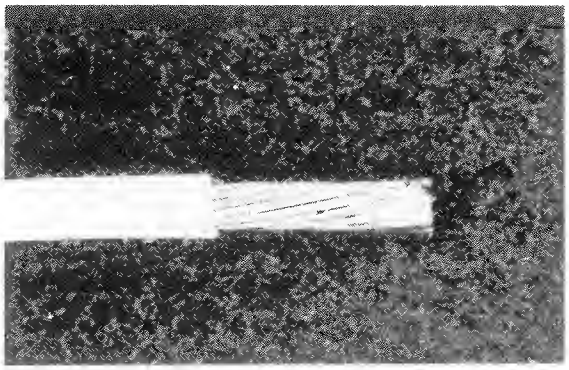
ACCEPTABLE (Preferred)
Full tin with wire outline visible.

ACCEPTABLE (Minimum)
Full tin with wire outline partially obscured by solder.

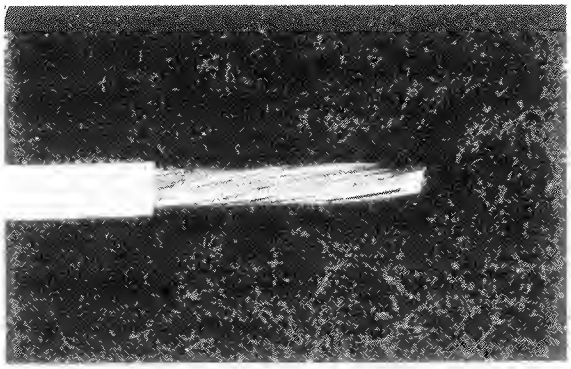
UNACCEPTABLE
Full tin with insulation melted, solder ball, wicking, and wire outline obscured.

Tip Tinning

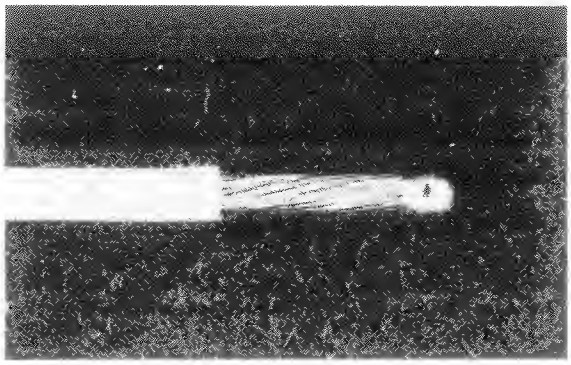
When tip tinning is specified, the stripped wire is tinned approximately 1/8 (0.125) inch to prevent fraying of the strands.



ACCEPTABLE (Preferred)
Tip tin with wire outline visible and just tip of wire tinned.



ACCEPTABLE (Minimum)
Tip tin with wire outline partially obscured.



UNACCEPTABLE
Tip tinning with excessive solder.

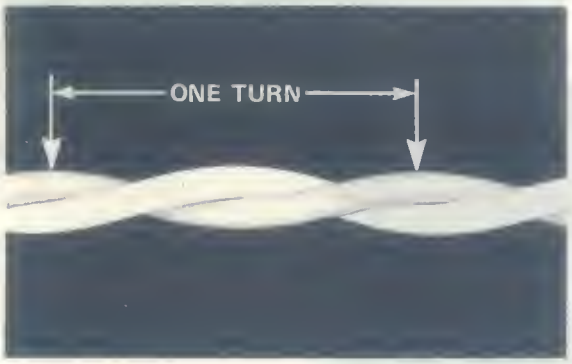
## TWISTED PAIRS

*General*

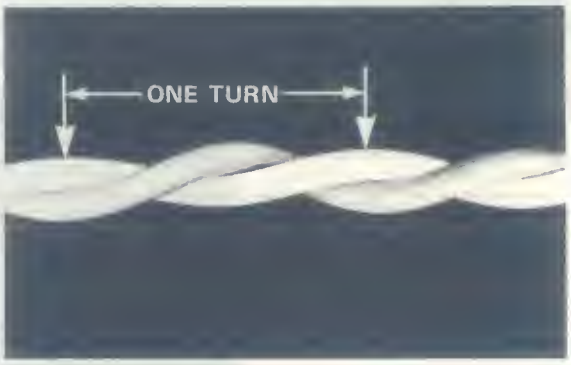
Twisted pairs shall be twisted uniformly per Table 1.2. This table may be used for twisting 2 or 3 wires. No wire shall pass between conductors of twisted pairs, sets of twisted pairs, triple twisted or sets of triple twisted.

TABLE 1.2

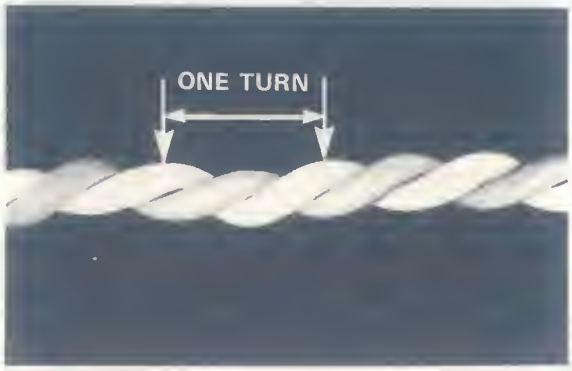
| CONDUCTOR SIZE (AWG) | LAY (NO. OF TURNS PER FOOT) 1 TURN = 360° TWIST OF WIRES | | CONDUCTOR SIZE (AWG) | LAY (NO. OF TURNS PER FOOT) 1 TURN = 360° TWIST OF WIRES | |
|---|---|---|---|---|---|
| | MINIMUM | MAXIMUM | | MINIMUM | MAXIMUM |
| 32 | 18 | 27 | 20 | 9 | 13 |
| 30 | 16 | 24 | 18 | 7 | 11 |
| 28 | 15 | 22 | 16 | 6 | 10 |
| 26 | 13 | 20 | 14 | 5 | 9 |
| 24 | 12 | 17 | 12 | 4 | 7 |
| 22 | 10 | 15 | 10 | 3 | 6 |




ACCEPTABLE (Preferred)
Twisted pairs are uniformly twisted using nominal values of Table 1.2.




ACCEPTABLE (Minimum)
Twisted pairs are uniformly twisted using the minimum or the maximum lay of Table 1.2

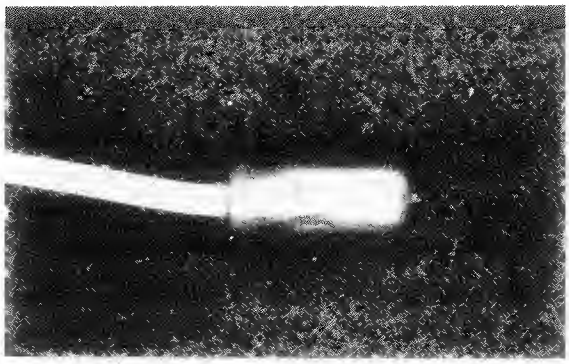



UNACCEPTABLE
Twisted pairs are not uniform and have lay less than the minimum or greater than the maximum of Table 1.2.

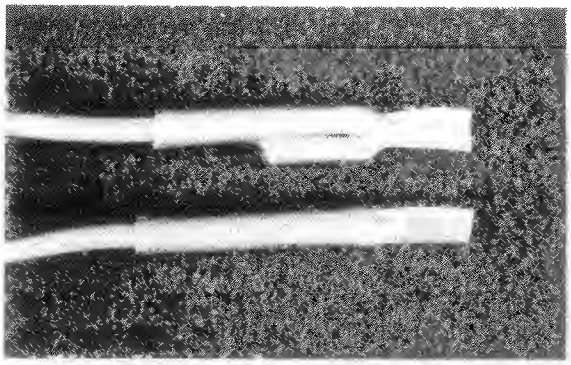
## UNTERMINATED WIRE

*General*

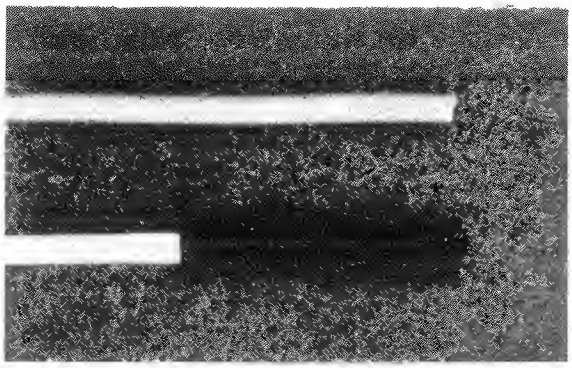
All spares or unterminated wires when required by engineering drawing should be individually terminated with a wire termination cap or shrink tubing and dressed neatly with the cable. Shrink tubing shall be a minimum of 1/4 inch over the end and 3/4 inch over the wire insulation.



ACCEPTABLE (Preferred)
Unterminated wire with an insulated wire termination crimped over the end of the wire.



ACCEPTABLE (Minimum)
Unterminated wire with a hook bent into the wire to prevent the insulation from stripping off.



UNACCEPTABLE
Unterminated wire shall not be acceptable when insulated with adhesive tape or cut off without insulating.

## BEND RADIUS

*Measuring*

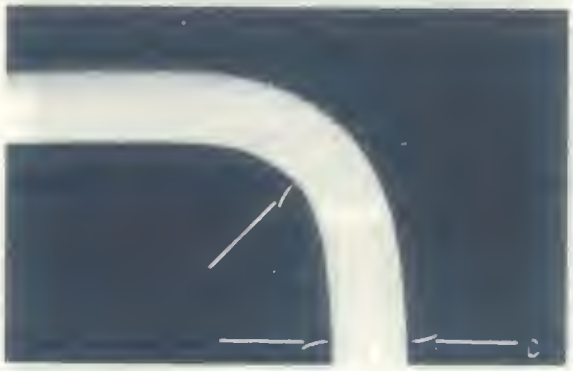
The bend radius is measured on the inside of the bend loop.

*Individual Wires*

The individual wires No. 10 AWG and smaller diameters, shall have a minimum radius of one and a half (1-1/2) times the outer diameter of the wire.

Individual wire diameters larger than No. 10 AWG shall have a minimum bend radius of three (3) times the outer diameter of the wire.

ACCEPTABLE (Preferred)
Typical bend radius for single wire forms a smooth bend and is one (1) wire insulation diameter larger than the minimum acceptable bend radius.



ACCEPTABLE (Minimum)
Typical minimum bend radius for single wire is smooth and uniform.

UNACCEPTABLE
Bend radius is too sharp and insulation is kinked.

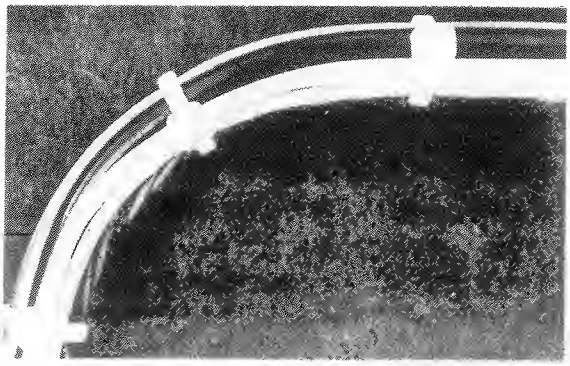
*Wire Bundles*

*Open*

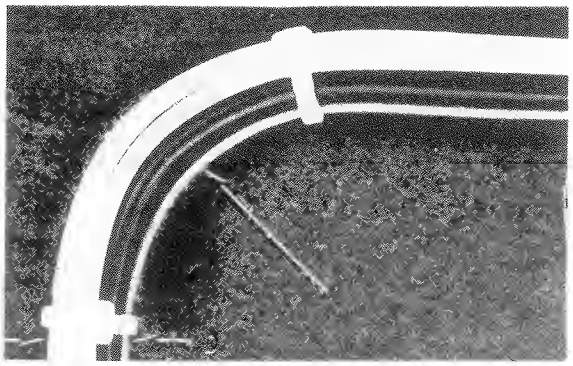
Harnesses formed from open bundles of wire shall have a radius of not less than one and a half (1 1/2) times the outer diameter of the bundle, except at connectors and terminals. At these terminations the minimum radius shall be three (3) times the bundle diameter.

*Sleeved*

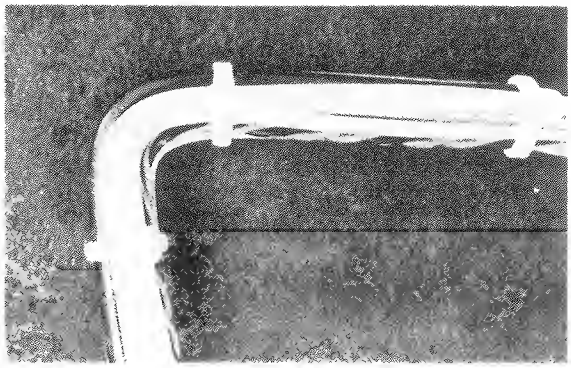
A harness enclosed in sleeving shall have a minimum radius of two (2) times the outer diameter providing the bend is performed prior to securing the ends.



ACCEPTABLE (Preferred)
Typical bend radius for wire bundle forms a smooth bend and is one (1) bundle diameter larger than the minimum acceptable bend radius.



ACCEPTABLE (Minimum)
Typical minimum bend radius for wire bundles is smooth and uniform.



UNACCEPTABLE
Bend too sharp.

*Shielded and Coaxial Cable*

Shielded and solid dielectric coaxial cable shall have a minimum bend radius of five (5) times the outside cable diameter. Coaxial cable with air dielectric shall have a minimum bend radius of eight (8) times the outside cable diameter.

*Multiconductor Cables*

Jacketed multiconductor cables shall have a minimum bend radius of four (4) times the outside cable diameter.

ACCEPTABLE (Preferred)
Bend radius for shielded and solid dielectric coaxial cables two (2) cable diameters larger than the minimum.

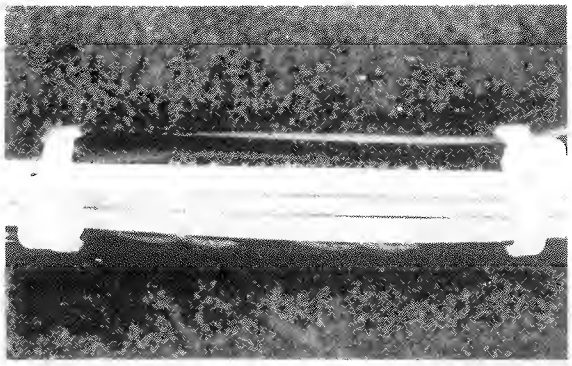
ACCEPTABLE (Minimum)
This is the minimum bend radius for shielded and solid dielectric coaxial cable.

UNACCEPTABLE
Bend is too sharp. Coaxial cable is kinked (see arrow).

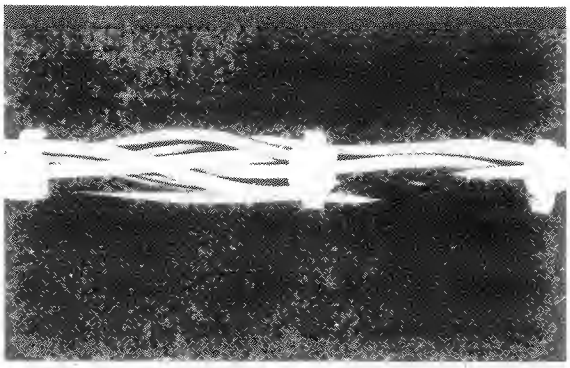
## HARNESS FABRICATION

*Wire Routing*

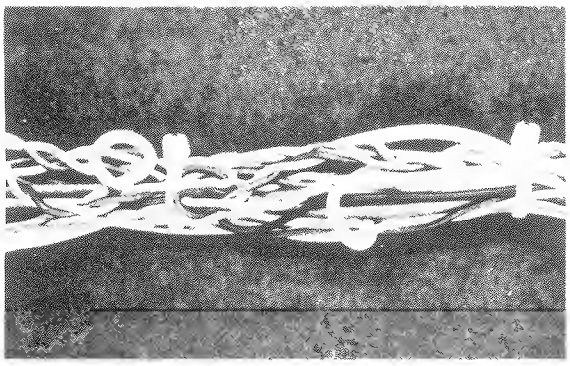
**Harness wire shall be routed parallel and with a minimum of cross-over (birdcaging).**



ACCEPTABLE (Preferred)
Wire routing with all wires parallel.



ACCEPTABLE (Minimum)
Wire routing with a minimum of cross-over.



UNACCEPTABLE
Wire routing with excessive cross-over (birdcaging of wires).

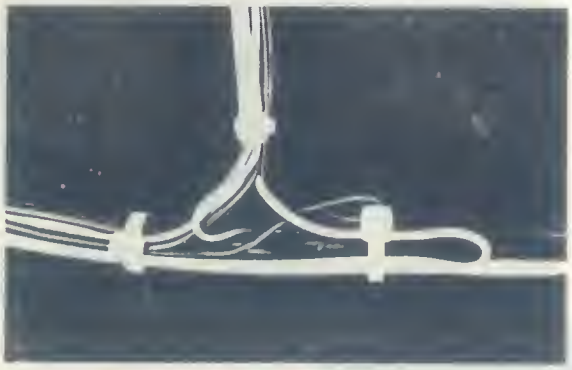
*Cross-Over*

Cross-over shall be made only at breakouts and ends; all other portions of the harness shall be parallel.

*Breakouts*

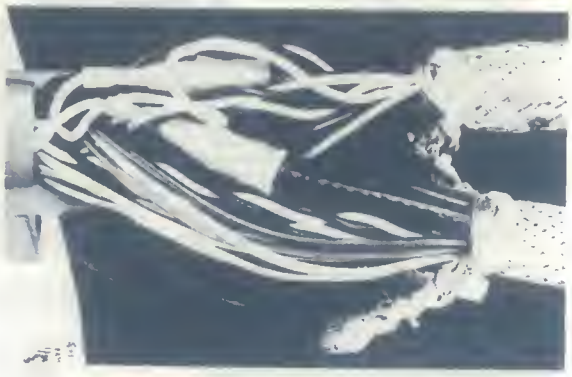
Wire shall break out per engineering specification drawings, or wiring harness board.

*NOTE:* Shown below are examples of generally "UNACCEPTABLE" conditions to be avoided where possible.



UNACCEPTABLE
Routing of wires with excessive length.

UNACCEPTABLE
Routing of wires at connector with excessive cross-over and bird-caging of wires.



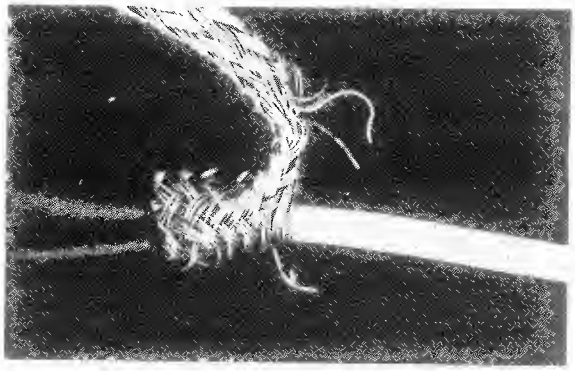
UNACCEPTABLE
Routing of wires with ferrules under strain relief, splice, birdcaging, and pigtail soldered too close to the shield breakout.

## CABLE

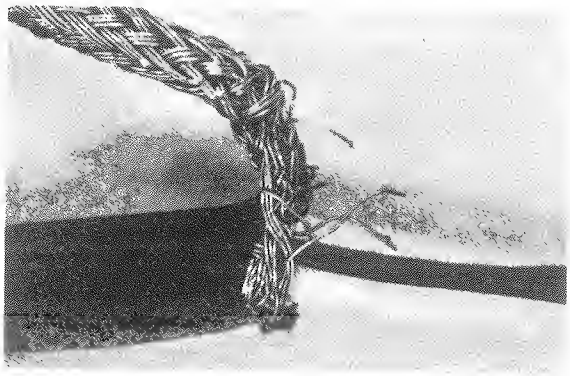
*Shield Pigtail*

When the inner conductor of a shielded or coaxial cable is brought out through the shield braid to form a pigtail, damage to shield strands or center conductor insulation is not acceptable.

ACCEPTABLE (Preferred)
Shield pigtail without broken or scraped wires; conductor insulation and jacket free from damage.



ACCEPTABLE (Minimum)
Shield pigtail with a maximum of broken or nicked strands per Table 1.1. (on page 1-6)



UNACCEPTABLE
Shield pigtail with an excessive amount of broken strands. Table 1.1.

*Tap Wire*

*Pigtail*

When a tap wire is soldered to a pigtail, the shield braid should be soldered a minimum of 1/4 (0.250) inch from the shield braid breakout. After soldering, the shield braid shall still be flexible at the breakout.

ACCEPTABLE (Preferred)
Tap wire, with a minimum of solder wicking and shield tightly soldered to tap wire. Outline of shield strands visible in solder.

ACCEPTABLE (Minimum)
Pigtail tap wire with solder a minimum distance from shield breakout and shield strands evident in the solder.

UNACCEPTABLE
Solder wicked to shield braid breakout, insulation overheated, tap wire improperly affixed to shield braid, and breakout is not flexible.

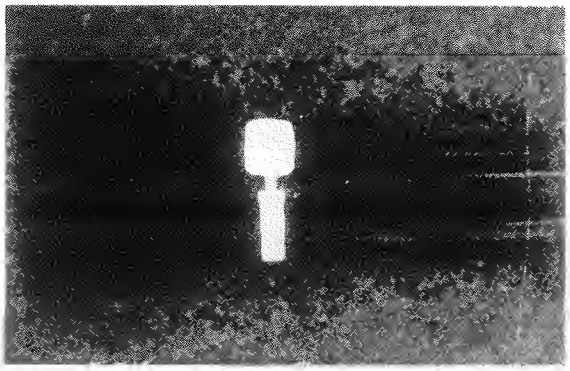
LACING (TIE WRAP)

*General*

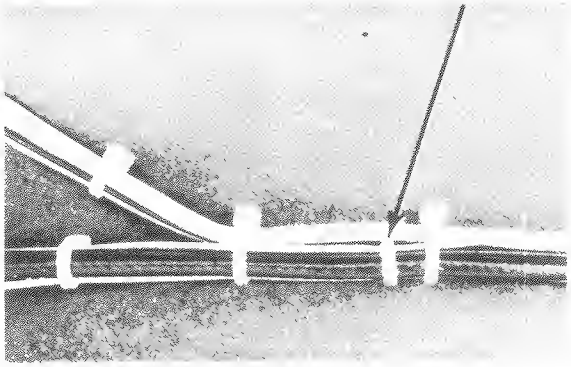
There are several methods of lacing wire bundles. Normally nylon tie wraps are the preferred method and are generally used.

*Bundle*

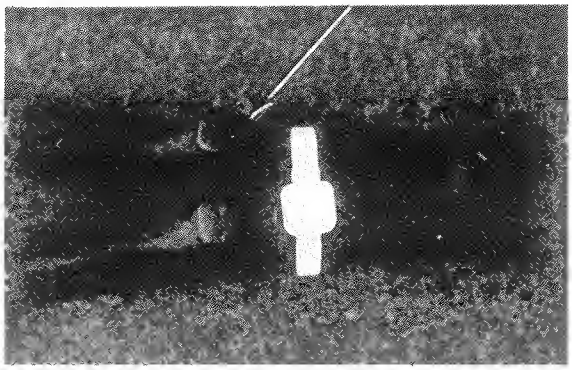
Where two or more conductors are combined into a bundle they should be secured. Where two or more bundles converge in the same harness and are tied together, the ties shall be removed from the individual bundles.



ACCEPTABLE (Minimum)
Conductors secured with a tie wrap.



UNACCEPTABLE
Converging bundles with ties not removed.



UNACCEPTABLE
Tie wraps under sleeving.

*Fanout*

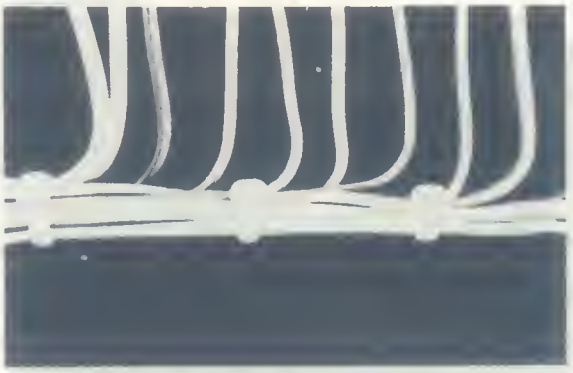
Tie wraps at fanouts shall be spaced a minimum of 1 inch between ties. Cord lacing may be placed at every fanout.

*Spacing*

The spacing must be neat and uniform in appearance. The following relationship between bundle diameter and maximum spacing between tie wraps shall be maintained. The minimum spacing for tie wraps shall be 1 inch and the maximum spacing shall be per Table 1.3. The diameter of a bundle is measured next to a tie wrap which is properly secured.

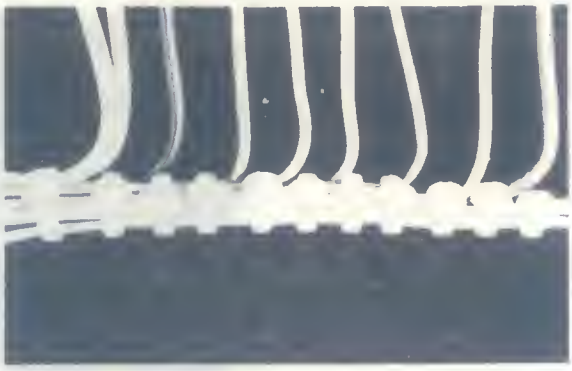
TABLE 1.3

| BUNDLE DIAMETER | TIE SPACING MAX. |
|---|---|
| 0 – 1/2 | 4 inches |
| 33/64 – 1 | 5 inches |
| 1 1/64 – 1-1/2 | 6 inches |
| Over 1-1/2 | 7 inches |



ACCEPTABLE (Preferred)
Tie wraps are spaced about one (1) inch apart.

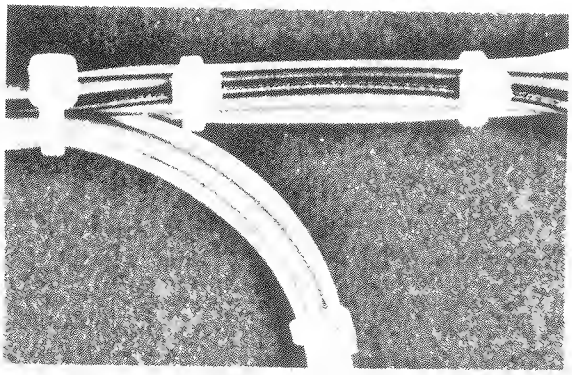
ACCEPTABLE (Minimum)
Tie wraps are minimum spaced at fanout.



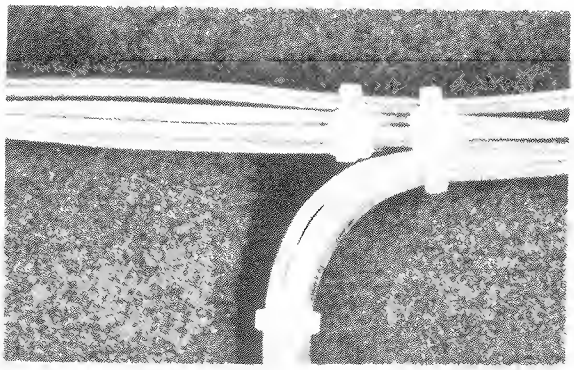
UNACCEPTABLE
Tie wraps are spaced less than the minimum at fanout.

*Branch*

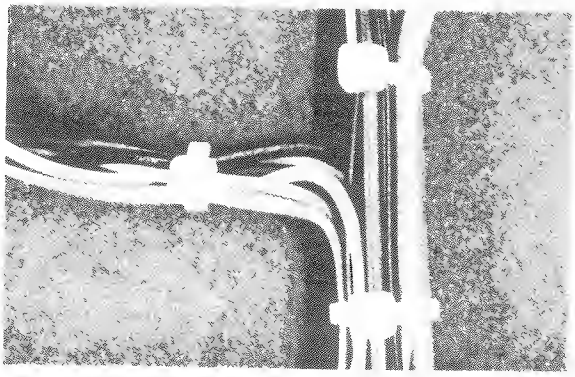
Tie wraps or cord lacing should be uniformly spaced on either side of the branch and as close to the branch as possible.



ACCEPTABLE (Preferred)
Branch with a bend radius of three (3) times the bundle diameter and have a tie before and after the breakout.



ACCEPTABLE (Minimum)
Branch with a bend radius a minimum of one and a half (1-1/2) times the bundle diameter and have a tie before and after the breakout.



UNACCEPTABLE
Branch with a bend radius less than one and a half (1-1/2) times the bundle diameter (bend too sharp), excessive cross-over.

*Tightness*

The tightness of the tie wraps must be sufficient to prevent slippage with normal handling, but, not so tight that wire insulation is deformed or cut.

*Shielded and Coaxial Cable*

Special attention shall be given so that lacing or tie wraps over shielding shall not be so taut that the shield is driven into the conductor.

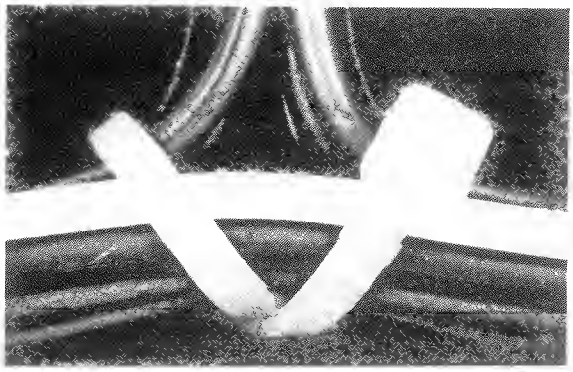
ACCEPTABLE (Preferred)
Tightness of tie wrap is when the tie wrap will not move laterally along the bundle, with normal handling but can be rotated in place.

UNACCEPTABLE
The tie wrap is deforming the insulation on the wire.

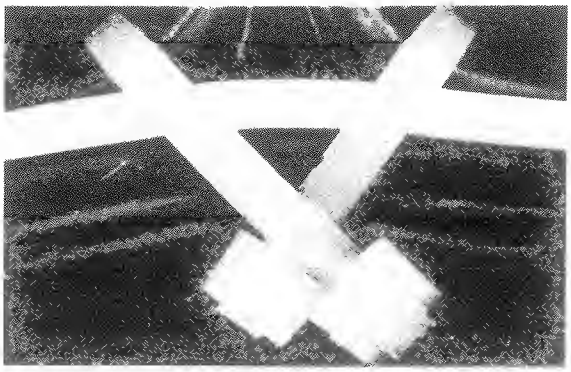
UNACCEPTABLE
Tie wrap is too loose, and will slip easily along the bundle with normal handling.

*"T" Branch*

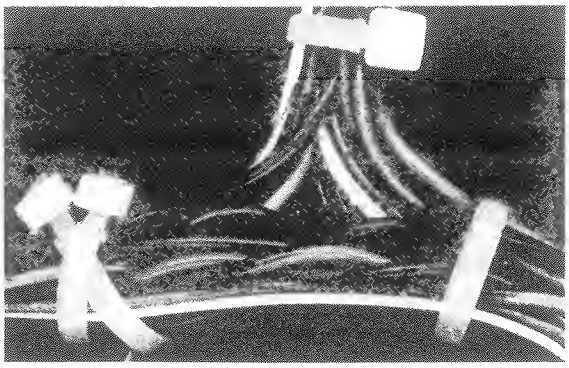
When a "T" junction is specified, the acceptable preferred method is the use of a figure eight. The minimum acceptable is to cross two (2) tie wraps at the branch.



ACCEPTABLE (Preferred)
This is an example of a figure-eight on a "T" branch.



ACCEPTABLE (Minimum)
This is an example of two (2) ties crossed on a "T" branch.



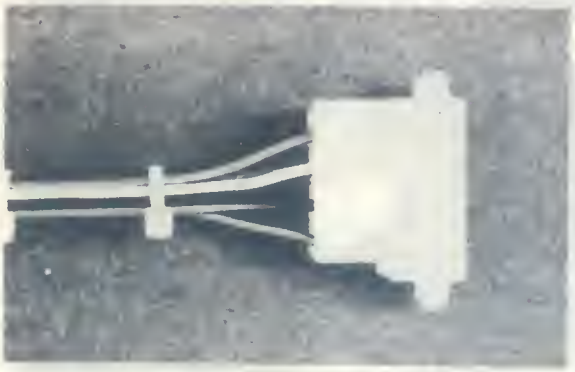
UNACCEPTABLE
"T" branch is not tight. Three ties are not acceptable for a "T" branch.

CONNECTORS

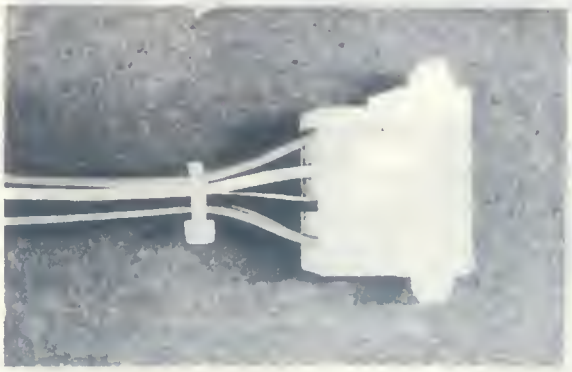
*General*

At connectors, the tie wraps must be as close as possible to the connector without placing mechanical strain on the wires.

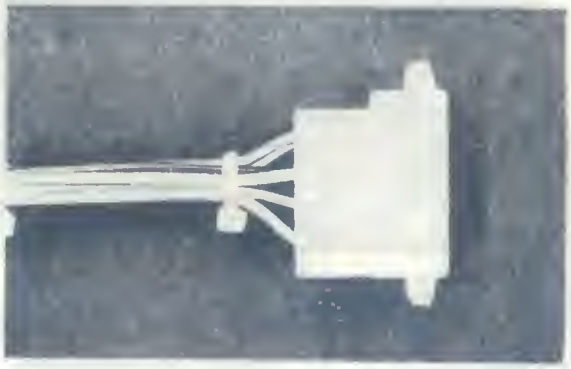
Wire flair-out is the point where the wires come together without being stressed at the connector.



ACCEPTABLE (Preferred)
Tie is approximately 1/4 inch beyond wire flair-out.



ACCEPTABLE (Minimum)
Wire flair-out is adequate to prevent leads from being stressed.



UNACCEPTABLE
Wire flair-out inadequate, wires under stress.

SLEEVING

*General*

Harnesses may be protected by flexible plastic or heat shrinkable tubing where specified, but adhesive tapes shall not be used for this purpose.

*Clear Shrink Tubing*

When an assembly requires inspection, non-transparent (opaque) shrink tubing may be used when in-process inspection is performed prior to application of shrink tubing.

*Size*

The size of the tubing or sleeving (excluding expanded shrink tubing) shall be a reasonable snug fit over the wire bundle and not obviously larger than necessary for assembly.

*Shrinking*

Heat shrinkable tubing shall not be used where the application of heat will damage the soldered joint or components. The amount of shrinking shall not cause splitting, cracking or unnecessary rigidity. Adequate shrinkage will have taken place when the contour of the wires being covered is visually discernible or when a clearly snug fit has been obtained.

TABLE 1.4

| DIAMETER | MINIMUM SLEEVING OVERLAP OF WIRE INSULATION |
|---|---|
| 0 – 1/8 | 1/4" |
| 17/64 – 1/2 | 1/2" |
| 33/64 – 3/4 | 3/4" |
| 49/64 – 1 | 1" |
| Greater than 1 inch | 1-1/2" |

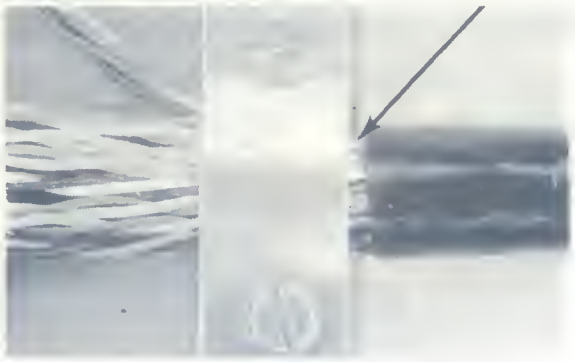
## STRAIN RELIEF

*General*

When sleeving or tubing is specified on cable or harness, the tubing should protrude 1/32 (0.031) inch minimum beyond the connector strain relief and be securely clamped along with the wire bundle.

ACCEPTABLE (Preferred)
Sleeving or tubing securely clamped 1/8 (0.125) inch beyond the strain relief clamp.

ACCEPTABLE (Minimum)
Sleeving or tubing securely clamped 1/32 (0.031) minimum inch beyond the strain relief clamp.

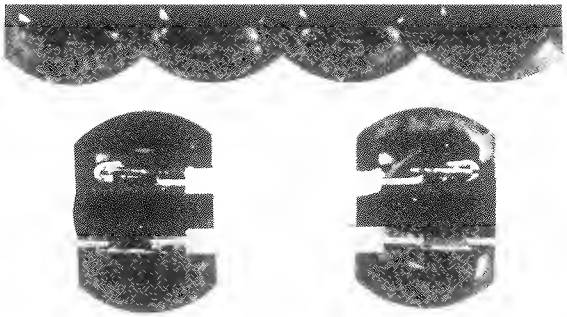


UNACCEPTABLE
Sleeving is not under the strain relief clamp.

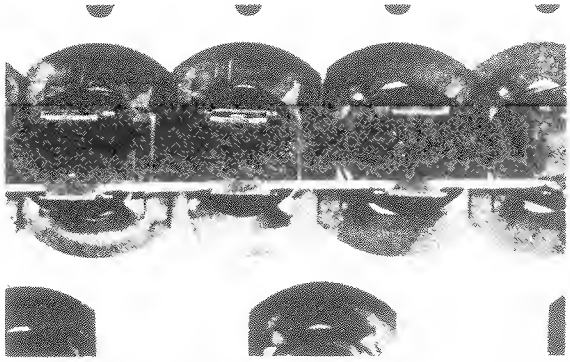
JUMPER WIRE

*General*

When specified on the engineering drawing, jumper wires shall be protected by sleeving. A maximum of 1/2 inch of bare wire will be allowed. Sleeving applied to leads must be of one continuous length between terminals.



ACCEPTABLE (Preferred)
Note acceptable sleeving installation of bus wire.



ACCEPTABLE (Minimum)
Unsleeved bus wire does not exceed 1/2 inch in length.

UNACCEPTABLE
The bare wire exceeds the maximum distance.

## CONNECTORS

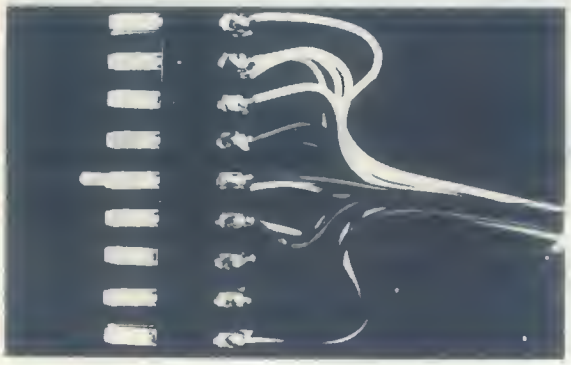
*Contact Damage*

Connectors with contaminated inserts (paint, adhesives, carbon, grease, oil, water, metal, chips, etc.) or with bent or corroded contacts are unacceptable.

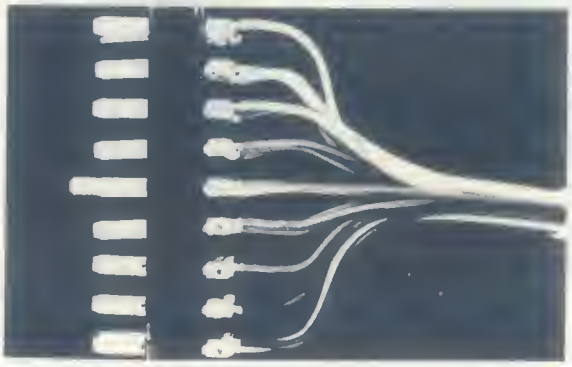
Straightening contacts: Straightening bent hollow connector contacts is not acceptable. Solid connector contacts bent 10° or less may be straightened providing no fracture occurs.

*Strain Relief*

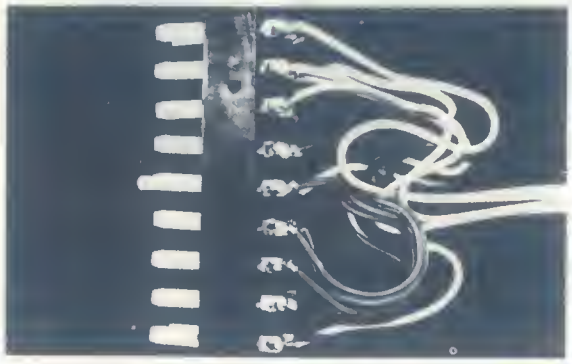
Individual wires shall be formed so as to provide natural strain relief for the connector terminations when cable is straightened. The contact floating characteristic must be preserved.



ACCEPTABLE (Preferred)
Wire formed to provide natural strain relief.



ACCEPTABLE (Minimum)
Wire with minimum service loop and strain relief.



UNACCEPTABLE
Wire with excessive service loop and strain relief, wires are bunching.

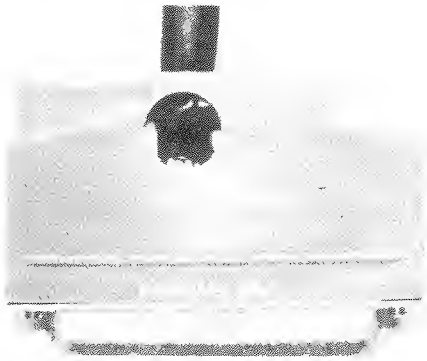
## STRAIN RELIEF OF JACKETS

*General*

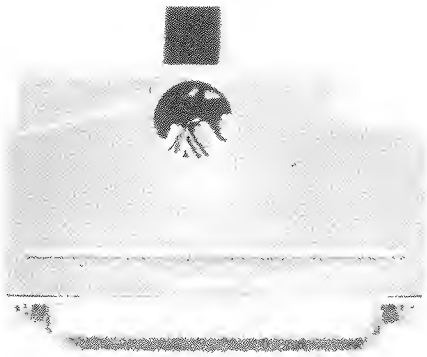
All connectors, paddle boards, etc., attached to cables shall be provided with an appropriate strain relief, using method indicated on assembly drawing. Whenever possible, strain relief shall be of proper size for bundle or cable used.

*Assembly*

The insulating tubing of jacket of a cable shall extend 1/8 inch minimum beyond the strain relief clamp or connector hood. This applies to connector hoods with open strain reliefs. The cable diameter shall be such that a good grip is obtained when the clamp is tightened on the connector. The clamp halves shall not bottom against each other when the screws are tightened.



ACCEPTABLE (Preferred)
Cable jacket shall be well into the hood of the connector. (Hood cut out for clarity.)



ACCEPTABLE (Minimum)
Cable jacket minimum distance beyond strain relief clamp.

UNACCEPTABLE
Cable jacket is not into connector strain relief clamp.

*Increasing Diameter*

If necessary, the cable diameter shall be increased by the addition of boots or layers of sleeving so that proper strain relief is obtained.

*Stress*

As the clamp is tightened, the wires attached to the connector should be checked to be certain that they are evenly formed out and that no wire is unduly stressed.

ACCEPTABLE (Preferred)
Cable is proper size for strain relief, clamp does not bottom when screws are tightened. (Hood cut away for clarity.)

ACCEPTABLE (Minimum)
Strain relief with increased diameter using sleeving, clamp does not bottom when screws are tightened.

UNACCEPTABLE
Strain relief clamp screw bottomed, increased diameter should be used.

*General Criteria to Determine ACCEPTABILITY*

The connector shall meet the following:

(a) No damage to inserts, contacts or threads.

(b) Minimum acceptable or preferred quality of crimped terminations.

(c) Proper seating of removable contacts.

(d) Nicked or cut conductor strands do not exceed Table 1.1. (on page 1-6)

(e) Clean inserts and contacts (light tarnish on silver plated contacts is not cause for rejection if plating is free of holes).

(f) Assembled connector parts shall be properly mated, fully seated and securely tightened.

(g) Hardware shall be uniform in type and size.

*General Criteria to Determine UNACCEPTABILITY*

Any evidence of the following conditions shall be cause to classify the connector assembly UNACCEPTABLE:

(a) Missing parts and/or sub-assemblies.

(b) Defective parts and/or sub-assemblies.

(c) Loose parts and/or assemblies.

(d) Improper installations of parts and/or sub-assemblies.

(e) Damaged parts and/or sub-assemblies.

(f) Marked or scratched surfaces which reveal the base/parent material or have raised burrs.

(g) Sharp burrs.

## TESTING

*Continuity*

As a minimum, testing should demonstrate that connections have been made only between the terminations shown on the engineering drawings or specifications.

*Procedures*

All cables and harnesses, when applicable, shall be tested in accordance with engineering test procedures.

## HANDLING AND TRANSPORTING

*General*

Cables and harnesses shall be assembled, tested, inspected, stored, handled, and transported so as to prevent physical damage to connections, insulation, and shielding, such that final use is not impaired.

*Harnesses*

Harnesses shall be transported and stored in containers initiated and/or approved by Industrial Engineering. Flexible cables three feet or longer may be rolled into a coil for transportation or storage.

*Cables*

When cables are coiled, the bend radius shall be at least ten (10) times the cable diameter and shall be tied with at least two (2) loose non-metallic ties to prevent unwinding. Cables shall be transported and stored in containers initiated and/or approved by Industrial Engineering. Connectors shall be suitably packaged to prevent damage.

REWORK/RETROFIT/REPAIR/PROCEDURES REFERENCES

| | |
|---|---|
| Cable Workmanship Standard | AS-P-7665049-0-0 |
| Cable Inspection & Test | AS-P-7665050-0-0 |
| Cable Location Marking | AS-P-7665111-0-0 |
| Twisted Pair Wire Stripper | AS-P-7665159-0-0 |

*NOTE:* Additional references can be obtained from Engineering Specification A-SP-7665000-0-0
(Format and Index Specification)

TABLE OF CONTENTS

SECTION 2.0 -- HARDWARE

## PURPOSE

The purpose of this section (2.0) is to establish and provide photographic representation of the ACCEPTABLE (PREFERRED), ACCEPTABLE (MINIMUM) and UNACCEPTABLE quality levels as they apply to HARDWARE. These requirements shall prevail when specific information does not appear on Engineering documentation. Engineering documentation may define specific quality requirements which take precedence over general workmanship standards.

## WORKMANSHIP

All details of workmanship shall be in accordance with high-grade industrial electrical assembly and equipment installation practices as reflected in the following standards.

## DEFINITIONS

*Ground*

A conducting path, intentional or accidental, between an electric circuit or equipment and the earth, or some conducting body serving in place of the earth.

*Hardware*

1. Electronic components, subassemblies, and finished pieces of equipment, as contrasted to a drawing board design.
2. Bolts, nuts, fasteners, brackets, handles and similar small structural parts used in assembling electronic equipment.

*Heat Sink*

A mass of metal that is added to a device for the purpose of absorbing and dissipating heat. Used with power transistors and many types of metallic rectifiers.

*Large Clearance Hole*

A large clearance hole is one where either the head of the screw or a washer/nut can be pulled into it.

## FASTENERS

*General*

With few exceptions, the true function of a screw/bolt is to clamp members together, and not to act as an axle, etc. The tension set up in the screw/bolt keeps joints tight. Two forces put stress on screw/bolts as they tighten: tension due to screw/bolt stretch, and torsion due to friction. But only tension remains after wrenching. In rigid joints if this tension exceeds external forces (forces created by member being clamped together), screw/bolts will never experience any further strain, and therefore, will not loosen or fail.

*Thread Forming Screws*

Another most important group of industrial fasteners are the thread forming screws. These screws roll, cut or otherwise form their own mating threads. Most thread forming screws are made of steel and are hardened on the outside surface. The core of the fastener is soft enough to accept torquing loads and the surface is hard enough not to gall or distort during the driving operation. Thread forming screws are generally used in material where large internal stresses are permissible or desirable to increase resistance to loosening.

*Damage*

Excessively burred or marred fasteners are not acceptable. Fasteners must not be damaged to the extent that removal would be difficult or where sharp burrs protrude. Visible hardware on completed assemblies shall be free from this type of defect.

## DEFINITION OF TIGHT

Because of the many variables affecting hand tightening, "tight" is defined as meaning the screw cannot be appreciably tightened further without damage to the threads or material. (See Table 2.1).

## TORQUE TABLE

*General*

Because of the many variables involved to determine absolute torque values the following table indicates approximate torque values as applied to DIGITAL's use of stainless steel machine screws.

TABLE 2.1

| THREAD SIZE | TORQUE (INCH POUNDS) |
|---|---|
| #4 | 7 |
| #5 | 11 |
| #6 | 13 |
| #8 | 26 |
| #10 | 30 |
| 1/4" | 98 |
| 5/16" | 172 |
| 3/8" | 312 |
| 1/2" | 850 |

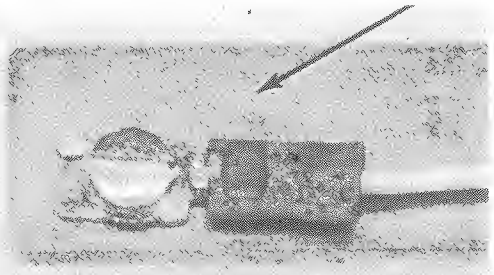
## ANODIZED AND PAINTED SURFACES

*Electrical Contact*

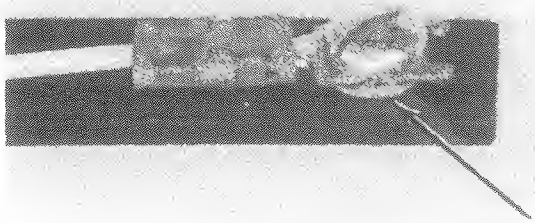
Anodized and painted surfaces shall not be used for electrical contact. (These finishes act as an insulation.)

An internal or external tooth lock washer may be used to break through the anodized/painted surface to make electrical contact with the base material or spot facing can be utilized.

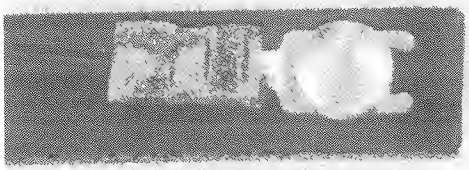
Where the fastener cannot make electrical contact with the base material, the anodize or paint finishes must be removed.



ACCEPTABLE (Preferred)
Base material is used for electrical surface contact.



ACCEPTABLE (Minimum)
An external or internal tooth washer must be used to break through the anodize/paint to make electrical contact.



UNACCEPTABLE
Anodized or painted surface used for electrical contact.

## WASHERS

*Flat Washers*

Flat washers will be used on standard buildup assemblies as a bearing surface for lock washers on non-metallic materials and metallic materials which have prominent exterior painted surface or finish.

*Large Clearance Hole*

Flat washers will be used as a bearing surface when large clearance holes or slots are used. (Hole is usually 1-1/2 times the diameter of the screw or greater.) If an electrical connection must be made under this condition, an external tooth lock washer must be used in place of the flat washer being sure that the untoothed portion of the washer is in contact with the surface.

*Cable Clamp*

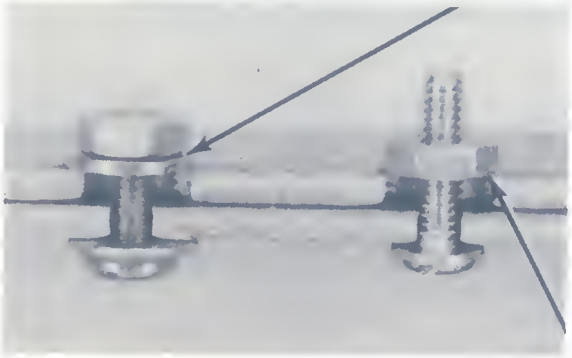
Flat washers shall be used on plastic type cable clamps or non-metallic surfaces.

*Terminal Block*

Flat washers are not required for mounting screws on multiple screw terminal blocks.

ACCEPTABLE (Preferred)
Large flat washer and lock washer used over slot. (Washer should be one and one half (1-1/2) times the hole diameter.)

ACCEPTABLE (Minimum)
Small flat washer used over slot. (Washer is slightly larger than hole.)



UNACCEPTABLE
Two (2) flat washers and no lock washer. No flat washer or lock washer.

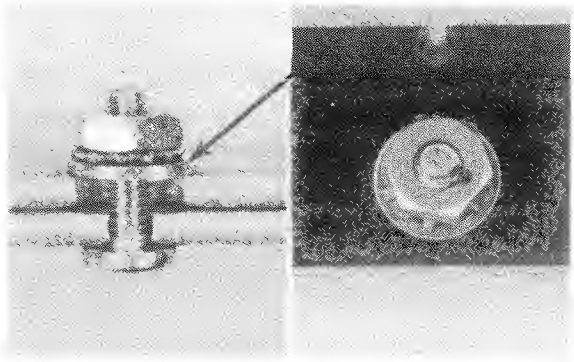
*Lock Washers*

Lock washers shall be used under all nuts (except self-lock types) and under the heads of all screws not secured by a lock nut or installed in a threaded hole. External tooth type lock washers are not acceptable for outside painted surfaces.

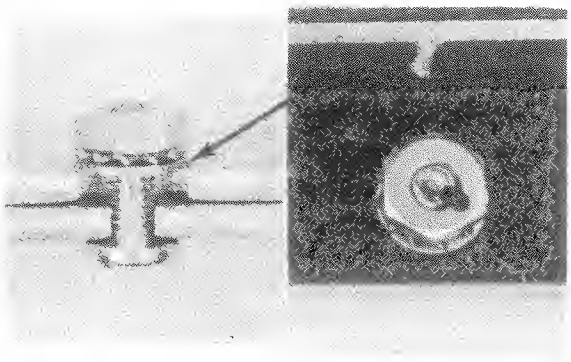
*Split Ring Lock Washers*

Spring lock washers must be used on all fastener assemblies intended for mechanical usage when screw size is 1/4 (0.250) inch diameter or larger.

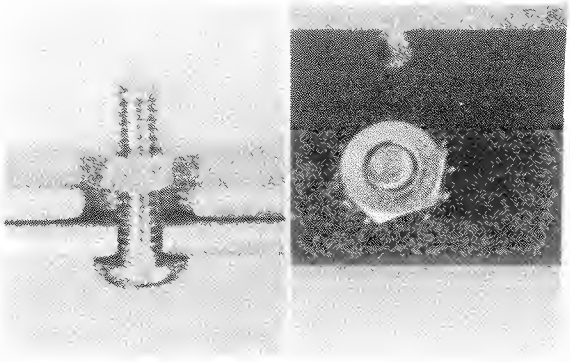
> *NOTE:* Internal/External Tooth Lock Washers – Internal/external tooth lock washer must be used on any grounding or current carrying fastener connection. Neither locking type terminal nor self locking nuts exclusively shall be used for electrical or current carrying connections.



ACCEPTABLE (Preferred)
An external tooth lock washer is used with a flat washer on a Printed Circuit Board; flat washer is larger than lock washer.



ACCEPTABLE (Minimum)
An external tooth lock washer is used with a flat washer on a Printed Circuit Board; flat washer is equal in size to the lock washer.



UNACCEPTABLE
An external tooth lock washer is used on a Printed Circuit Board. No flat washer used.

## SCREW PROTRUSION

*General*

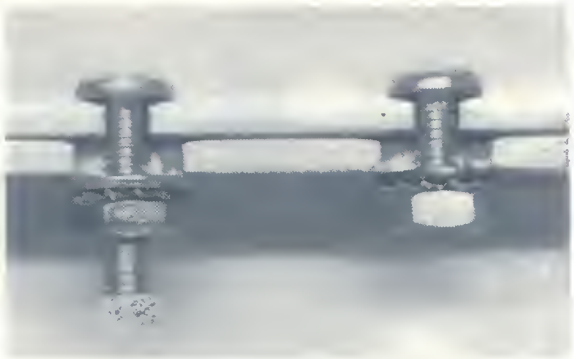
The screw protrusion out of the nut shall be flush with the surface of the nut as a minimum and shall not exceed 1/8 (0.125) inch maximum beyond the surface of the nut.

*Thread Engagement*

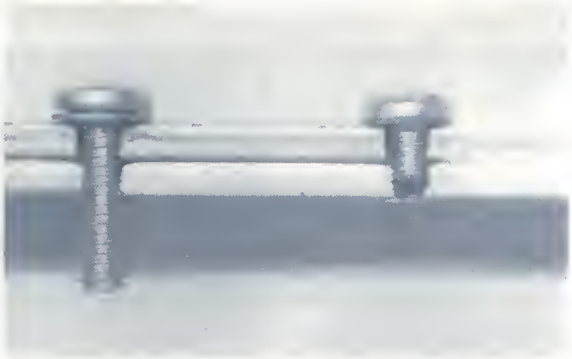
The length of thread engagement for tapped holes in steel or hard brass shall be at least equal to the nominal diameter of the threads.

Thread engagement for tapped holes in aluminum, magnesium, or other soft materials shall be at least 50% greater than steel.

ACCEPTABLE (Preferred)
Threads protrude through the nut, 3 threads.



ACCEPTABLE (Minimum)
Threads protrude a maximum of 1/8 (0.125) inch. As a minimum the screw is flush with the surface of the nut.



UNACCEPTABLE
Thread protrusion is greater than 1/8 (0.125) inch. Screw not flush with the surface.

MECHANICAL FASTENER

*General*

Plated steel, or stainless steel fasteners should be used for all mechanical assemblies requiring fasteners.

*Tapped Hole*

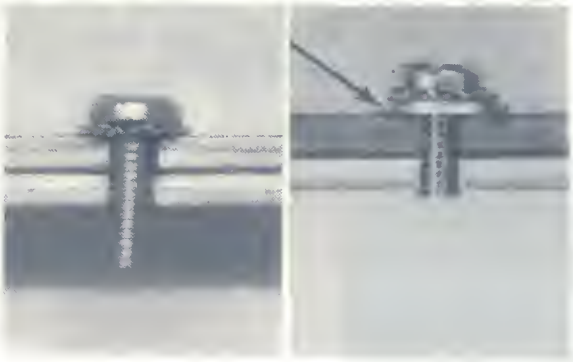
Metallic assembly with a tapped hole or permanently assembled threaded fastener or insert shall be assembled with a lock washer and appropriate screw.

*Non-Metallic Surface*

Non-metallic, prominent exterior painted surface, finish, metal with a slot, or large clearance hole assembled to a tapped hole shall be assembled with a flat washer, lock washer, and appropriate screw.

*Blind Hole*

Screws assembled into a blind hole shall seat tightly between the screw head and part. No clearance is allowable.



(BLANK)

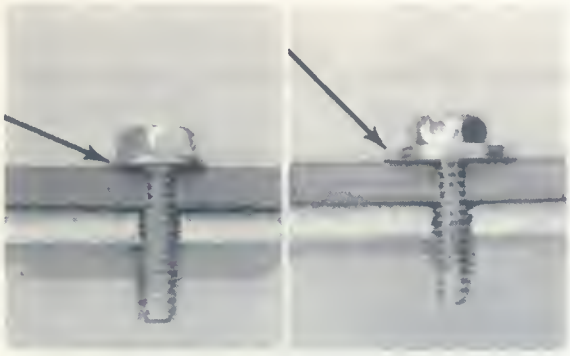
ACCEPTABLE (Preferred)
Screw with lock washer on metallic surface. Screw with flat washer and lock washer on non-metallic surface.

ACCEPTABLE (Minimum)
There are no minimum acceptable conditions that apply.

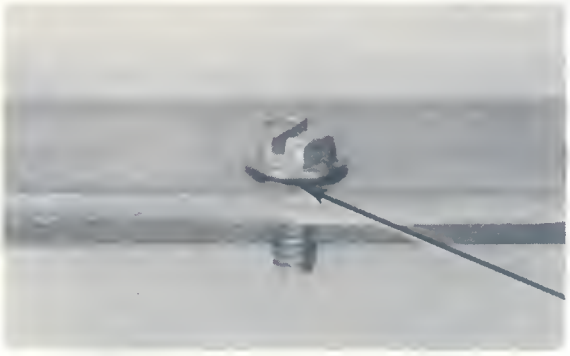
UNACCEPTABLE
Screw with no lock washer. Screw with lock washer on non-metallic surface.

*Thread Cutting Screw*

When fastening a metallic surface with a clearance hole to a metallic or non-metallic surface to be threaded by a screw with an indented hexagon washer head, no washer is required.



ACCEPTABLE (Preferred)
(#8 thread cutting screw used as example.)
Thread cutting screw assembled with the proper clearance hole, an indented hexagon washer head screw, or plain hexagon head screw with a washer.



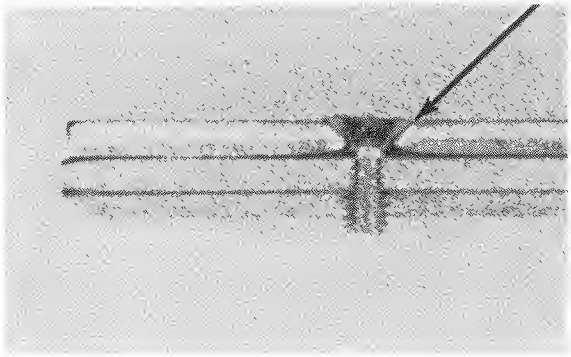
ACCEPTABLE (Minimum)
Thread cutting screw assembled with the proper slotted clearance hole and an indented hexagon washer head.

UNACCEPTABLE
Thread cutting screw used on slotted hole with plain hexagon head.

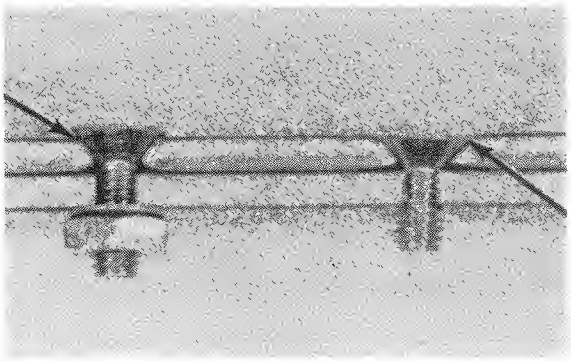
*Flat Head Screws*

Flat head screws shall be flush with the surface when properly installed and tightened. The head protrusion shall be a maximum of 1/64 (0.015) inch. The head depression shall be a maximum of 1/64 (0.015) inch.

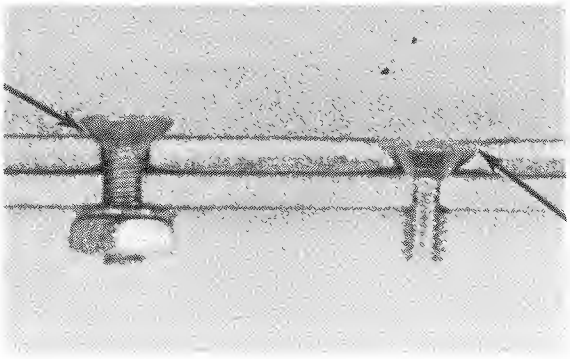
*NOTE:* Flat head screws used on surfaces over which moving assemblies (example: sliding drawer) are placed must be flush or below the surface, no protrusion.



ACCEPTABLE (Preferred)
Head flush with surface.



ACCEPTABLE (Minimum)
Head protruding or depressed 1/64 (0.015) inch from the assembly surface.



UNACCEPTABLE
Head protruding or depressed greater than 1/64 (0.015) inch from surface of assembly.

ELECTRICAL FASTENER

*Stud Mounted Components (Example)*

The stacking of hardware for stud mounted components shall be shown when isolation from the mounting plate is required.

ACCEPTABLE (Preferred)
Stud mounted component mounted using an insulating bushing.

(BLANK)

ACCEPTABLE (Minimum)
There are no minimum acceptable conditions that apply.

UNACCEPTABLE
Stud mounted component mounted with shrink tubing in place of nylon bushing.

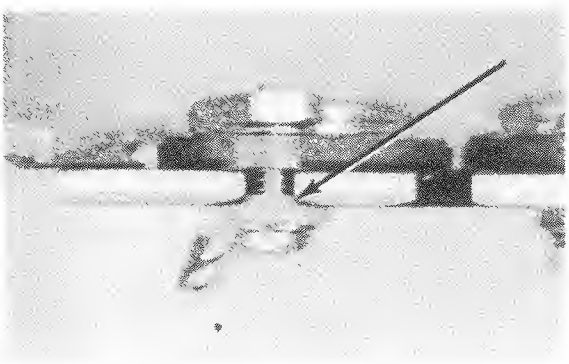
*NOTE:* See Figure 1 (on page 2-12) for application of thermal compound.

*Heat Sink*

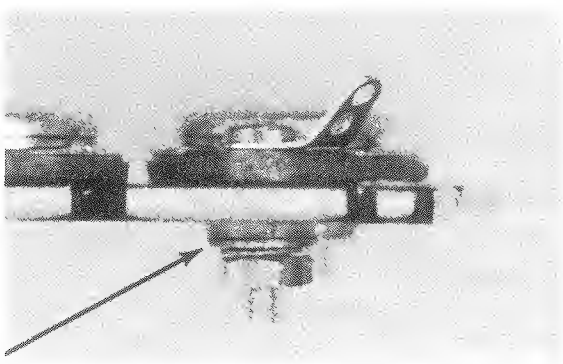
Heat sinks are used to dissipate heat from the heat generating component. Transistor and diode mounted on heat sink shall have thermal compound applied to both surfaces. (See Figure 1 on page 2-12.)

*Electrical Isolation*

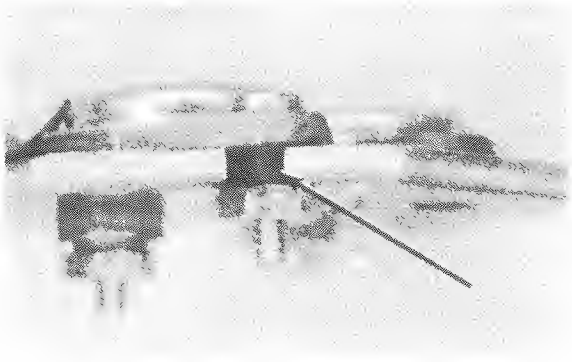
When transistors or diodes require electrical isolation from the heat sink, they shall use nylon bushings or other approved insulators and washer as shown below.



ACCEPTABLE (Preferred)
Transistor is mounted with thermal compound. Flat washer used on nylon insulator with a lock washer.



ACCEPTABLE (Minimum)
Transistor is mounted with thermal compound on both surfaces. Screws are mounted with lock washers.



UNACCEPTABLE
Transistor mounted without thermal compound. Screws mounted without lock washers.

## THERMAL COMPOUND

When specified thermal compound shall be used on all transistors, diodes, silicon controlled rectifiers, etc., that are mounted on heat sinks. Where a mica is used to isolate the device from the heat sink, both surfaces shall be coated with thermal compound as shown below.

*CAUTION:* A thin coating of thermal compound is all that is required. Large amounts of thermal compound will squeeze out from under device and will be picked up by handling, contaminating the entire assembly with thermal compound.

*NOTE:* Unless otherwise specified the type of thermal compound used shall be "Wakefield 128".

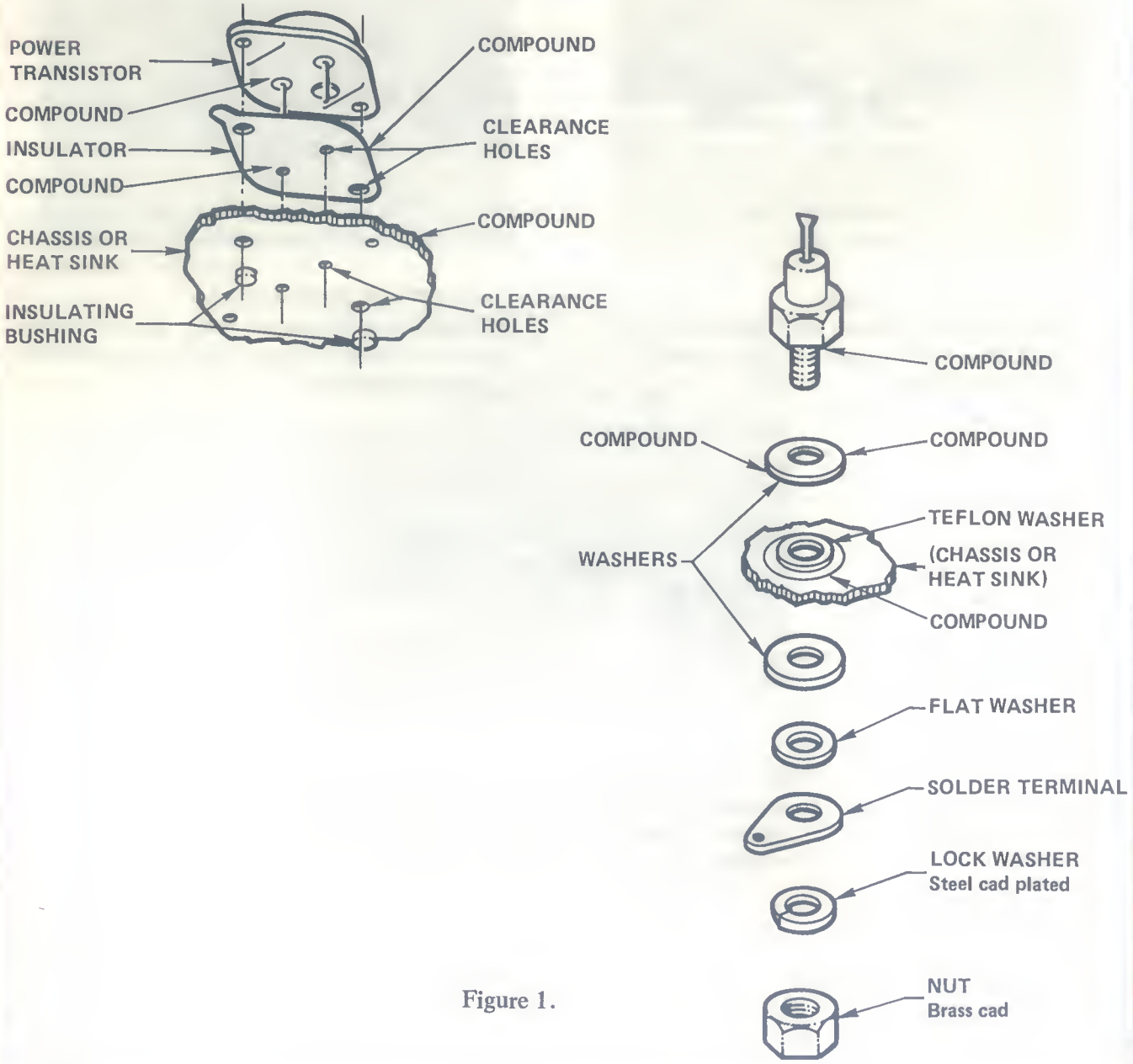



Figure 1.

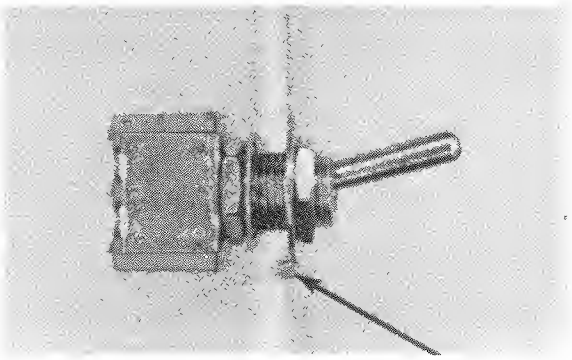
## SWITCHES AND POTENTIOMETERS

*General*

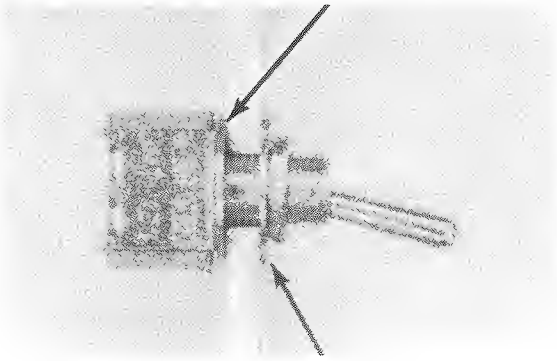
Switches and potentiometers shall be mounted with a flat washer on the operation side except when a knurled nut is used.

A locking device (example: internal tooth lock washer) shall be used with every switch/potentiometer on the component side of the mounting surface.

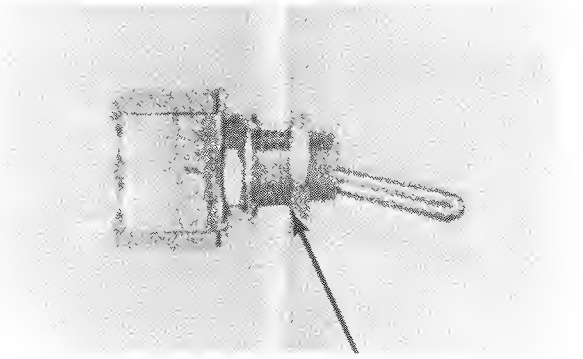
Switches and potentiometers supplied with orientation tabs, to orient and prevent component from turning, may be used without a lock washer when holes are provided for the tabs.



ACCEPTABLE (Preferred)
Orienting pin on panel and flat washer on operator side.



ACCEPTABLE (Minimum)
Lock washer behind panel. Flat washer on operator side. No nut between panel and switch body.



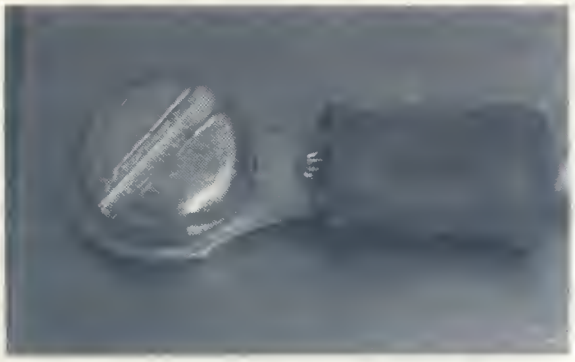
UNACCEPTABLE
No flat washer used on operator side.

## ELECTRICAL CONNECTIONS TO CHASIS

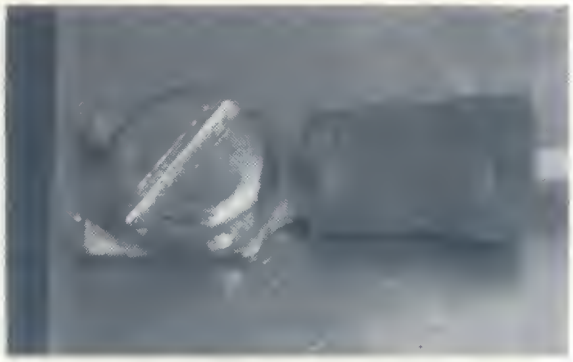
*General*

Electrical connections to the chassis must use a lock washer or toothed ground lug. Connections to anodized aluminum must use an internal tooth lock washer or internal toothed ground lug bearing directly on the anodized (insulating) film. Split ring lock washers are not acceptable for connections to anodized aluminum.

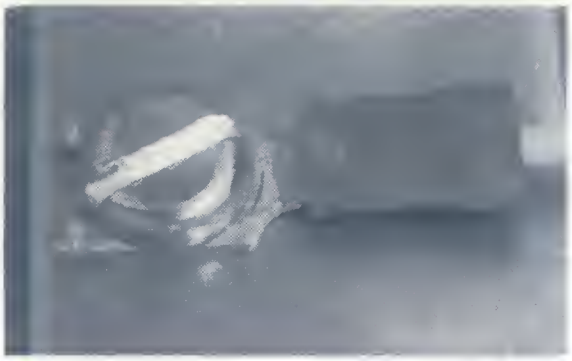
Primary circuit ground shall have a compression crimped ring tongue or retainable spade lug mounted on the chassis with a binder head screw.



ACCEPTABLE (Preferred)
Preferred chassis ground shall have a ring tongue or locking fork compression crimped terminal, an internal toothed lock washer under the ring tongue or locking fork terminal and a binder head screw.



ACCEPTABLE (Minimum)
Primary chassis ground shall have a retained compression crimped terminal lug with a binder head screw. Threads and area of contact must be clear of paint or other insulating finishes.



UNACCEPTABLE
Chassis ground with unretained spade lug.

RIVETS

*General*

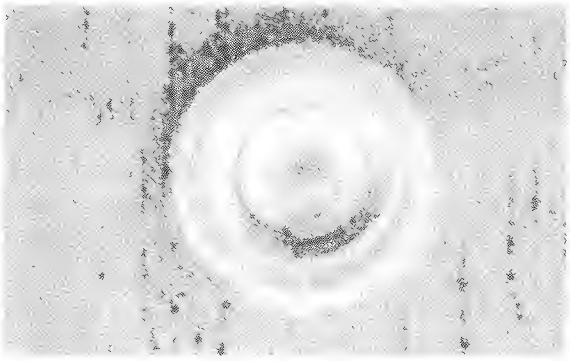
Rivets that are solid, eyelet, or tubular shall meet the following:

a) Cracks or splits in the rolled or plated portion of eyelets shall be permissible within the following limits:

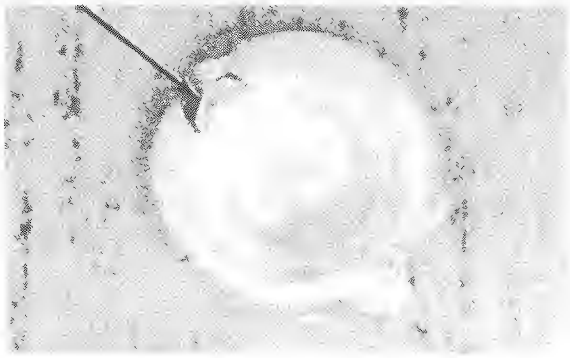
(1) No single part may have more than three minor cracks or splits around the outside diameter.

(2) No crack or split shall extend into the shank.

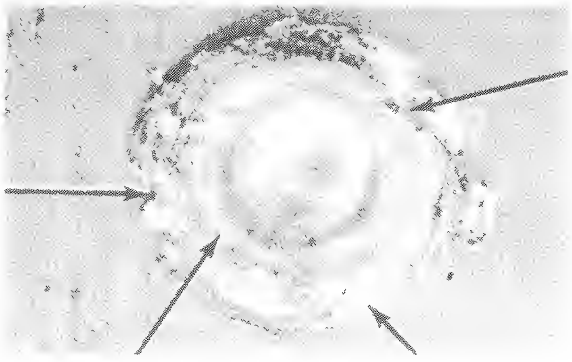
b) Rivets and eyelets shall be tight. The staking or rolling shall be uniform and the heads fully seated.



ACCEPTABLE (Preferred)
Rivet free of cracks or splits.



ACCEPTABLE (minimum)
Rivet with a maximum of three minor cracks or splits.



UNACCEPTABLE
Rivet with major cracks or splits.

SECURING SCREWS

Use of Glyptol, Loctite, or Acceptable Substitute is preferred.

Screws on printed circuit boards which are secured with glyptol etc., insulating varnish at the intersection of the nut and screw after tightening shall conform to the following: Glyptol, etc., must not be so thin that a fillet cannot be formed between the nut and the screw.

ACCEPTABLE (Preferred)
Glyptol/Loctite has formed a fillet at the junction of the nut and screw.

ACCEPTABLE (Minimum)
Glyptol/Loctite has formed a minimum fillet at the junction of the nut and screw.

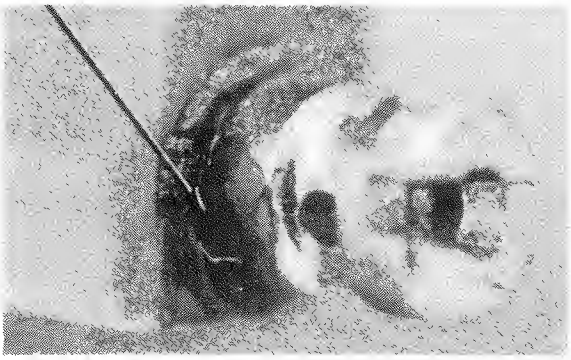
UNACCEPTABLE
No Glyptol/Loctite.

## ADJUSTMENT SCREWS

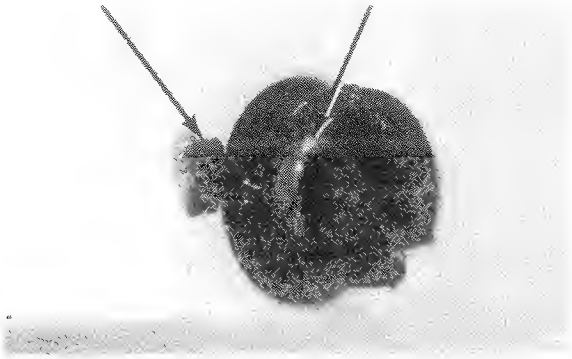
*Trim Pot Adjustment Screws*

Upon completion of calibration (test) trim pots adjustment screws may be secured with Glyptol at the junction of the screw head and the component body.

ACCEPTABLE (Preferred)
The Glyptol has formed a fillet at the junction of the screw head and the body.



ACCEPTABLE (Minimum)
The Glyptol has formed a minimum fillet at the junction of the screw head and body.



UNACCEPTABLE
The screw head and body have Glyptol on them but a fillet was not formed by the Glyptol.

RETROFIT/REPAIR/REWORK/PROCEDURES REFERENCES:

| | |
|---|---|
| Touch-up Spec | A-SP-7665022-0-0 |
| HARDWARE ASSEMBLY SPEC | A-SP-7665099-0-0 |

*NOTE:* Additional references can be obtained from Engineering Specification A-SP-7665000-0-0 (Format and Index Specification.)

TABLE OF CONTENTS

SECTION 3.0 – LOGIC ASSEMBLIES/WIRE WRAP

## PURPOSE

The purpose of this section (3.0) is to establish and provide photographic representation of the ACCEPTABLE (PREFERRED), ACCEPTABLE (MINIMUM) and UNACCEPTABLE quality levels as they apply to LOGIC ASSEMBLIES/WIRE WRAP. These requirements shall prevail when specific information does not appear on Engineering documentation. Engineering documentation may define specific quality requirements which take precedence over general workmanship standards.

## WORKMANSHIP

All details of workmanship shall be in accordance with high-grade industrial electrical wiring and equipment installation practices as reflected in the following standards.

## DEFINITIONS

*A turn of wire.*

A turn of wire shall consist of one complete, single, helical ring of wire wrapped 360° around a wire wrap pin, intersecting four corners of the pin. A connection having "n" turns in contact with the wire wrap pin will intersect the reference corner "n + 1" times.

*Buss Wiring*

Wiring with a solid conductor which is used to permanently connect two or more terminals together.

*End tail.*

An end tail is the end of the last turn of wire of a solderless wrapped connection which may extend in a tangential direction instead of resting against the wire wrap pin.

*Gas-tight area.*

The gas-tight area is that area between the wire wrap pin and wire which, due to the quality of the wrap, will exclude gas fumes.

*Solderless wrapped connection.*

This connection consists of a helix of continuous, solid, uninsulated wire tightly wrapped around the wire wrap pin of a solderless wrapped contact to produce a mechanically and electrically stable connection. The number of turns required will depend on the gauge of wire used. In addition to the length of uninsulated wire wrapped around the wire wrap pin, an additional, minimum, half turn of insulated wire shall be wrapped around the pin to help insure better vibration characteristics. To accomplish a half turn, the insulated wire must be in contact with at least three corners of the wire wrap pin. See Figure 2. (on page 3-2)

*Solderless wrapped, electrical connection.*

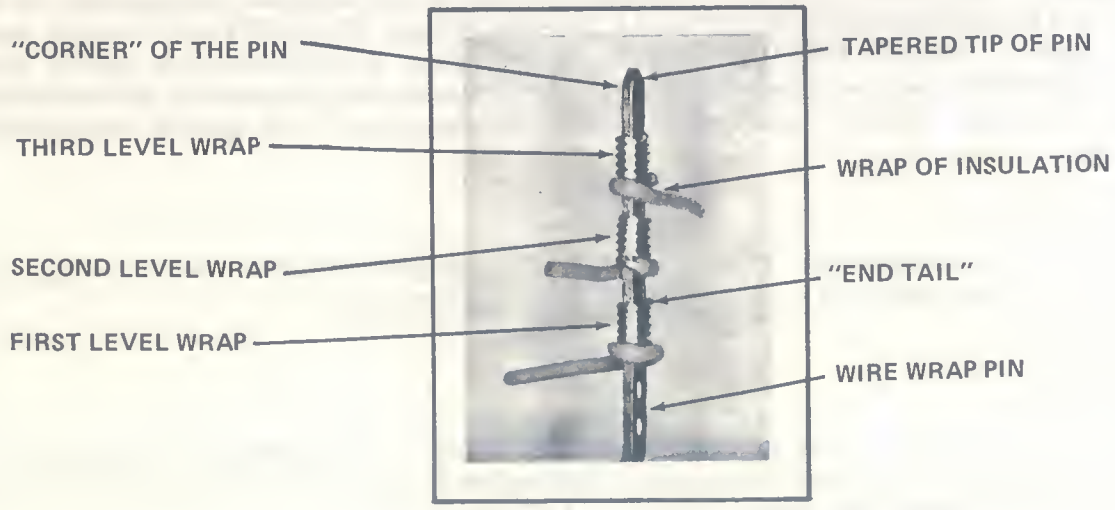
The terminology and makeup of this type of connection on one type of wire wrap pin configuration is illustrated on Figure 1.

*Twisted Pair.*

A cable composed of two insulated conductors twisted together without a common covering.

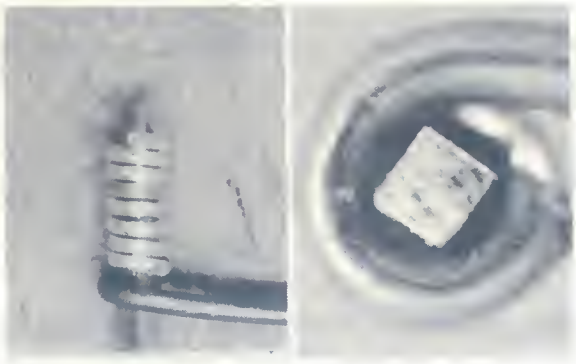
*Wire Wrap*

See "Solderless wrapped connection".



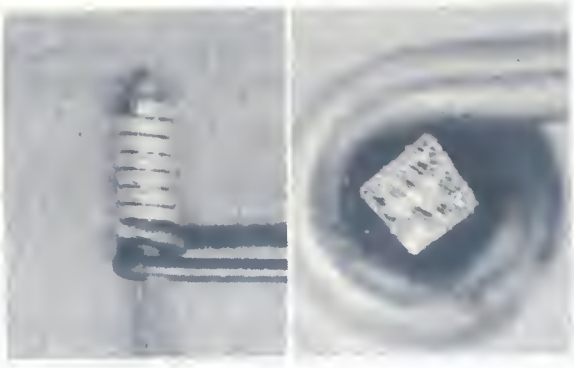

(The connecting block and other posts have been eliminated from the picture for clarity.)

Figure 1



HALF TURN
Insulated wire contacting a minimum of three (3) corners of the wire wrap pin.

Figure 2



ONE FULL TURN
Insulated wire contacting all four (4) corners of the wire wrap pin.

Figure 3

WRAPPING LEVELS

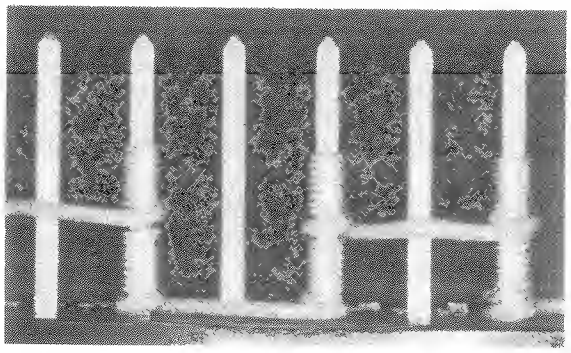
Wraps shall normally be positioned on common levels of the wire wrap pin (i.e., each end of the wrapped wire must be on the same level). The wraps shall be so spaced as to allow for a minimum of three (3) levels.

If necessary, LEVEL JUMPING is acceptable when:

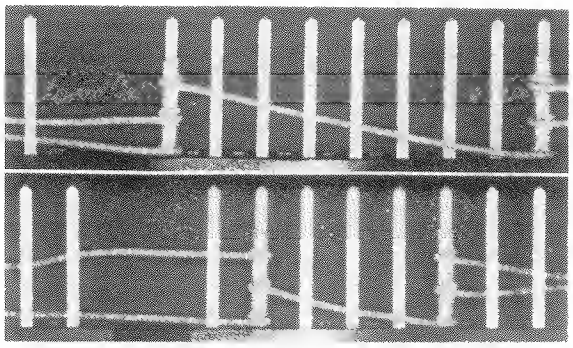
a. a one (1) level jump occurs over a four (4) pin spread between the connected ends.

b. a two (2) level jump occurs over an eight (8) pin spread between the connected ends.

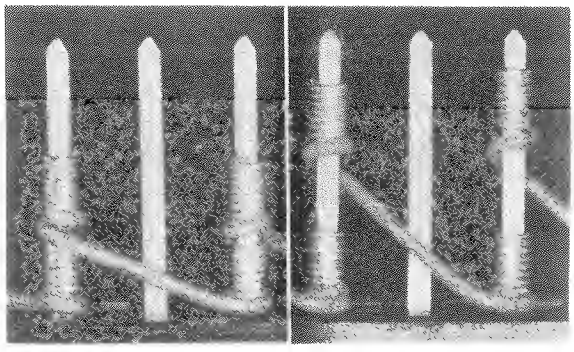
*NOTE:* Twisted pairs and triple twisted wires are not governed by this requirement.



ACCEPTABLE (Preferred)
Wraps are on common levels of the wire wrap pins (examples shown are #24 gauge wire on 144 pin connector block).



ACCEPTABLE (Minimum)
Two (2) level jump is minimum of eight (8) pins away. One (1) level jump is minimum of four (4) pins away.



UNACCEPTABLE
Wraps are not on common levels and do not conform to the four (4) and eight (8) pin spread requirement.

## WIRE

*General*

The wire for solderless wrapped electrical connections (wire-wrap) shall meet the following:

(a) Only solid (single conductor) wire shall be used.

(b) Conductors shall not be cut or nicked in excess of 10% of the cross section of the wire.

(c) The insulation shall not be damaged to the point where the conductor is visible through it.

## CONNECTIONS

*Turns*

The minimum acceptable number of turns for #24 through #30 AWG wire shall be in accordance with Table 3.1 on page 3-12.

ACCEPTABLE (Preferred)
Uninsulated wire with 5 turns and insulated wire with 1 turn. (Examples shown are #24 gauge wire on 144 pin connector block.)

(BLANK)

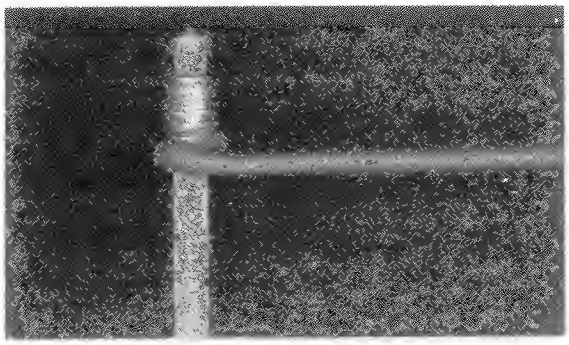
ACCEPTABLE (Minimum)
The minimum acceptable conditions shall be in accordance with Table 3.1.

UNACCEPTABLE
Insufficient number of turns, uninsulated and insulated wire.

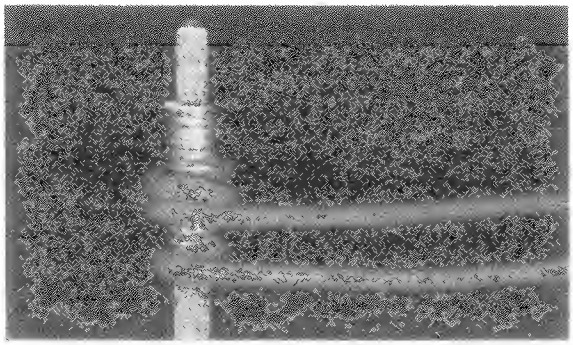
OVERLAP (PILE WRAPS)

*General*

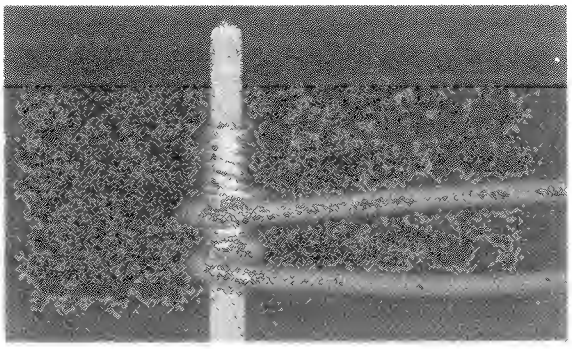
There shall be no overlappings (bare wire turns which overlap one another). The first two (2) turns of insulation may overlap the last turn of uninsulated wire in a connection below it on the same wire wrap pin.



ACCEPTABLE (Preferred)
All strands adjacent to each other. (Examples shown are #24 gauge wire on 144 pin connector block.)



ACCEPTABLE (Minimum)
First two (2) turns of insulated wire on top wrap overlaps last turns of uninsulated wire on lower wrap.



UNACCEPTABLE
Insulated and uninsulated turns of wire on top wrap overlap last turns of uninsulated wire on lower wrap.

## SPIRAL WRAPS

*General*

There shall be no spiral wrap. The maximum cumulative spacing between full turns of uninsulated wire shall be no greater than one half (½) the bare wire diameter.

ACCEPTABLE (Preferred)
All turns tight against each other. (Examples shown are #24 gauge wire on 144 pin connector block.)

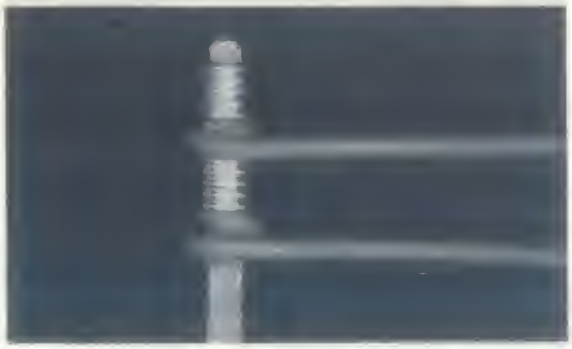
ACCEPTABLE (Minimum)
Turns with gaps (cumulative) not exceeding 1/2 the diameter of the bare wire.

UNACCEPTABLE
Spiral wrap or a gap between the turns exceeding 1/2 the diameter of the bare wire.

## MULTIPLE WIRE WRAP CONNECTIONS

*General*

Under normal conditions the top turn of the uppermost wire wrap connection should not extend into the tapered portion of the wire wrap pin. However, in the event that the correct number of turns (minimum) is on the untapered portion of the wire wrap pin, the connection shall be considered acceptable.



ACCEPTABLE (Preferred)
Top turn of uppermost connection stops prior to reaching the tapered portion of the wire wrap pin (Examples shown are #24 gauge wire on 144 pin connector block.)

ACCEPTABLE (Minimum)
Minimum number of turns are on the untapered portion of the wire wrap pin.

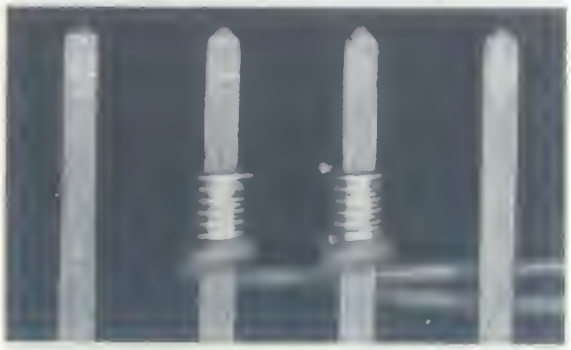
UNACCEPTABLE
Less than the minimum number of turns of wire are on the untapered portion of the wire wrap pin.

## WIRE WRAP END TAILS

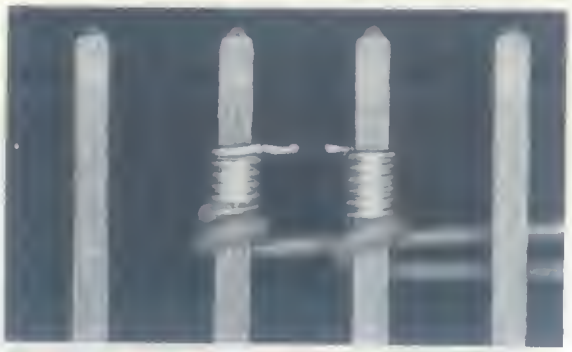
*General*

The completed wrap shall not have an end tail that extends beyond the last edge contacted on the wire wrapping by more than one (1) uninsulated wire diameter. The minimum clearance between wire wrap ends and other wire wrap pins or uninsulated conductors is 1/16 (0.063) inch.

ACCEPTABLE (Preferred)
Tails are tight against the wire wrap pin (examples shown are #24 gage wire on 144 pin connector block.)



ACCEPTABLE (Minimum)
Tails extend to one (1) wire diameter away from wire wrap post and has the minimum 1/16 (0.063) inch clearance between pins.



UNACCEPTABLE
Tails extend beyond one (1) wire diameter away from wire wrap pin and has less than 1/16 (0.063) inch clearance between pins.

## WIRE AND WIRE WRAP PIN RE-USE

*General*

The portion of the wire that has been previously wrapped shall not be used for making a new connection. A new section of wire must be used.

Wire wrap pins which have been previously used for wrapped connections may be reused, provided corrosion or excessive plating loss has not occurred. Corner indentations and slight pin distortion caused by previous use is acceptable.

## ROUTING AND DRESS

*General*

Lead dress shall be such that the connection does not tend to unwrap and the wires lay below the top of the wire wrap pin.

To avoid damage to wire insulation, wires must be routed and dressed so they are not tightly drawn against sharp edges of the pins to which they are not connected. There shall be no tension on the wires after both ends are terminated.

Normally wires should be routed for the shortest practical length. Allow enough slack when routing a wire around an unused pin to allow a wire wrap tool to be placed over the pin without damaging the wire passing by.

## MISCELLANEOUS WIRE WRAP INFORMATION

*Color Code For All Wire Wrapping*

| | | |
|---|---|---|
| Engineering Change Orders (ECO's) | Kynar | Green |
| Ground Lugs | | White |
| Hand Wrap (Repair) | Kynar | Blue |
| Machine Wrap | | |
| Gardner Denver | Yellow | (#30 AWG Kynar)<br>(#24 AWG Teflon) |
| Semi Automatic | Kynar | (Orange #24, Yellow #30, AWG<br>Blk/Wh TWP #30 AWG Kynar<br>Rd/Wh TWP #30 AWG Kynar<br>Gr/Blk/Wh Triple Twisted |
| | Millene | (#28 AWG) |

## WIRE WRAP REPAIRS

*General*

All repairs, ECO's and rework must be performed in the following manner:

(a) A wire-wrap joint must *never* be forced to lower level.

(b) A wire must *never* be reused.

(c) When changing a wire-wrap joint, either strip a new section of the wire or replace it entirely.

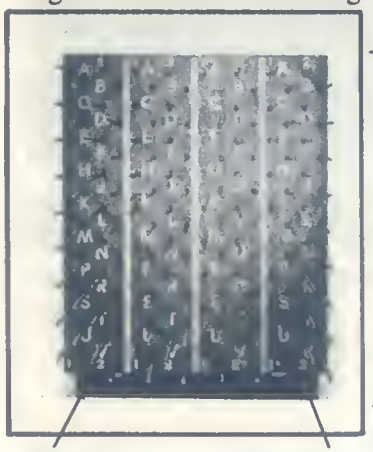
(d) Always use the correct color wire.

(e) When working on a panel containing modules, be sure a drain wire is connected between an air-driven tool and the chassis ground, and that AC-powered tools are operated from an isolation transformer.

(f) See page 3-13 for additional information.

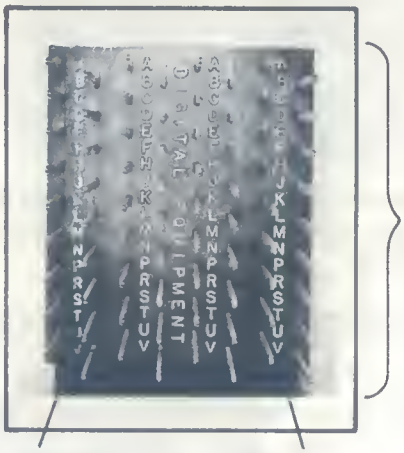
## WIRE-WRAP PIN LOCATION STANDARD

It is necessary to be able to locate the 'from' and 'to' end of any wire-wrap 'run'. The 'from' and 'to' is indicated by a series of six letters and numbers such as 1A24F1. The first number identifies the bay or cabinet (1A24F1). Since most small systems have only one bay, the first digit is usually not listed. The first letter identifies the horizontal row (A24F1). Refer to Figures 4 & 5. The rows are lettered starting with 'A' from the top of the bay. The second and third digits identify the vertical column or 'slot' in a particular row (A24F1). Refer to Figures 4 & 5. The second letter identifies the pin (wire-wrap post) in a given row and column (A24F1). There are 18 letters used; A through V. The letters G, I, O, and Q are not used. There are twice as many 30 gauge pins as 24 gauge pins in a slot. The last digit (1A24F1) identifies the left or right pin group in a 30 gauge socket (see Figure 4C). A '1' indicates the left hand group and '2' the right hand group. This last digit is not listed for a 24 gauge connector.



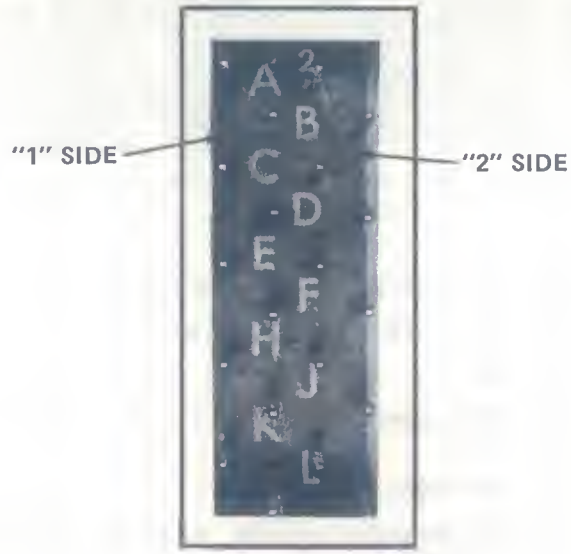

Top Half of a 30 Gauge Connector (288 wire wrap pins)

Figure 4A.




Top Half of a 24 Gauge Connector (144 wire wrap pins)

Figure 4B.




Close Up of 30 Gauge "Slot 1"

Figure 4C.

Figure 4. Examples of 30 and 24 Gauge Connectors

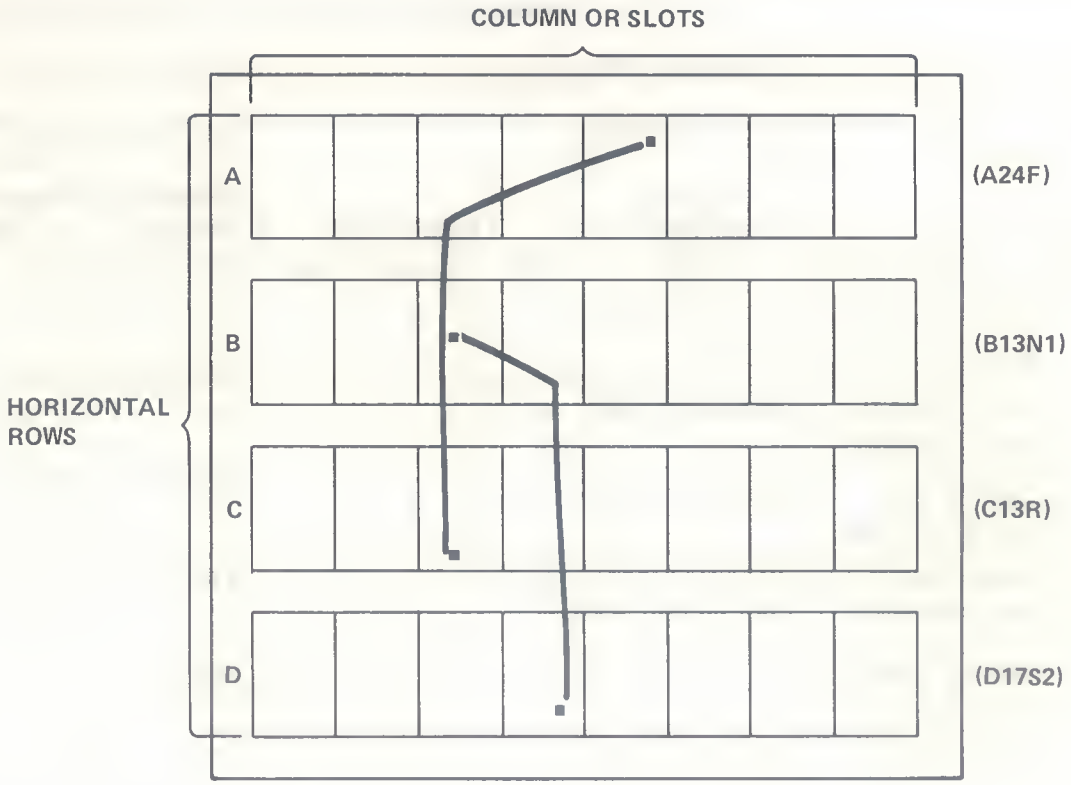



Figure 5. Wire Wrap Pin Location Standard
(Example shown is on 144 pin connector block.)

TYPICAL WIRE RUN (Reference Figure 5)

A typical "run" on 144 pin connector block would be:

From A24F to C13R (thus, a 24 gauge wire would run from row A, slot 24, pin F, to row C, slot 13, pin R.)

A typical "run" on a 288 pin connector block would be:

From B13N1 to D17S2 (thus, a 30 gauge wire would run from row B, slot 13, pin N1 to row D, slot 17, pin S2.)

On larger panels every fifth slot, starting at slot 5, is identified by a piece of red spaghetti pushed over pin A1. It is fairly easy, therefore, to locate a particular slot by counting from the nearest red marker.

TABLE 3.1

| Wire Gauge | Connector Type | Stripping Length (Inches) | Turns of Wire | | | Turns of Insulation | | Pull Test Requirements (lbs) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Recom. | Max | Min | Max | Min | Max |
| #24 | 144 Pin (H800W) Part #12-02244 | 1-3/16 + 1/16" | 4-1/2 | 6 | 6 | 1/2 | 2 | 7 | 35 |
| | 18 Pin (H802) Part #12-02625 | 1-3/16 + 1/16" | 4-1/2 | 6 | 6 | 1/2 | 2 | 7 | 35 |
| | 288 Pin (H803) Part #12-05348 | 28/32 + 1/16" | 4-1/2 | 6 | 6 | 1/2 | 2 | 4 | 30 |
| | 36 Pin (H807) Part #12-09123 | 28/32 + 1/16" | 4-1/2 | 6 | 6 | 1/2 | 2 | 4 | 30 |
| #26 | 144 Pin (H800W) Part #12-02244 | 1-1/4 + 1/16" | 6 | 7 | 7 | 1/2 | 2 | 6 | 35 |
| | 18 Pin (H802) Part #12-02625 | 1-1/4 + 1/16" | 6 | 7 | 7 | 1/2 | 2 | 6 | 35 |
| | 288 Pin (H803) Part #12-05348 | 1 + 1/16" | 6 | 7 | 7 | 1/2 | 2 | 4 | 30 |
| | 36 Pin (H807) Part #12-09123 | 1 + 1/16" | 6 | 7 | 7 | 1/2 | 2 | 4 | 30 |
| #28 | 288 Pin (H803) Part #12-05348 | 7/8 + 1/16" | 6 | 7 | 7 | 1/2 | 2 | 4 | 30 |
| | 36 Pin (H807) Part #12-09123 | 7/8 + 1/16" | 6 | 7 | 7 | 1/2 | 2 | 4 | 30 |
| #30 | 288 Pin (H803) Part #12-05348 | 1 + 1/16" | 7 | 8 | 9 | 1/2 | 2 | 4 | 30 |
| | 36 Pin (H807) Part #12-09123 | 1 + 1/16" | 7 | 8 | 9 | 1/2 | 2 | 4 | 30 |

REPAIR/REWORK/PROCEDURES REFERENCES:

| | |
|---|---|
| Solder Masked Panels | A-SP-7665006-0-0 |
| Resistance Soldering | A-SP-7665012-0-0 |
| Wire Wrap Inspection Criteria | A-SP-7665013-0-0 |
| Solder Mask | A-SP-7665015-0-0 |
| Wire Wrap Inspection Tag | A-SP-7665023-0-0 |
| Wire Wrap Tooling Calibration | A-SP-7665027-0-0 |
| Semi-Automatic Wire Wrap | A-SP-7665033-0-0 |
| Connector Block Repair | A-SP-7665034-0-0 |
| Bus Splicing | A-SP-7665098-0-0 |
| Omnibus Inspection | A-SP-7665119-0-0 |
| Reprofit/Rework Specification | A-SP-PDP10-0-RWRK |

*NOTE:* Additional references can be obtained from Engineering Specification A-SP-7665000-0-0 (Format and Index Specification).

TABLE OF CONTENTS

SECTION 4.0 – PRINTED CIRCUIT BOARDS/MODULES

TABLE OF CONTENTS (Cont.)

## PURPOSE

The purpose of this section (4.0) is to establish and provide photographic representation of the ACCEPTABLE (PREFERRED), ACCEPTABLE (MINIMUM) and UNACCEPTABLE quality levels as they apply to PRINTED CIRCUIT BOARDS/MODULES. These requirements shall prevail when specific information does not appear on Engineering documentation. Engineering documentation may define specific quality requirements which take precedence over general workmanship standards.

## WORKMANSHIP

All details of workmanship shall be in accordance with high-grade industrial electrical wiring and equipment installation practices as reflected in the following standards.

## DEFINITIONS

The following are some terms and definitions which have specific meaning when applied to printed-wiring and printed-circuit nomenclature. Where two or more acceptable terms are used to designate an item or process, one is defined and the others are cross-referenced by the word "see".

*Acceptable Minimum*

Acceptable minimum is the lowest degree of quality that will be accepted.

*Access Hole*

See "Terminal Hole".

*Adhesion*

See "bond strength".

*Ambient Temperature*

Temperature of the surrounding area.

*Artwork*

Artwork is an accurately scaled configuration which is used to produce the master circuit pattern.

*Base Laminate*

The base is the insulating support for printed-wiring or printed-circuits.

*Base Material*

The base material is the insulating material comprising the base laminate.

*Blister – Interlaminar*

An interlaminar blister is a void produced under the surface of a laminated material and is a form of delamination.

*Blister – Foil*

A foil blister is a localized separation between the base material and the conductive material.

*Blow Holes*

Blow holes are joints where contaminates were trapped in the plated hole and expanded with the application of heat in the soldering process. The expansion forces the joint to out gas.

*Board Thickness*

Printed board thickness is the overall thickness of the base material and the conductive material.

*Bond Strength*

Bond strength is a measure, in pounds per square inch, of the force required to separate a layer of conductive material from the adjoining base by a perpendicular pull applied to the surface of the conductive material.

*Bridging*

Bridging is the formation of a conductive path between conductors.

*Bus Wire*

A solid conductor used to connect two or more terminals. There are two types: insulated and noninsulated.

*Checking*

Checking is a surface condition evidenced by fine hairline cracks.

*Clinched Lead*

A component lead, when passed through the printed circuit board, that is bent toward the conductor equal to or greater than 45°.

*Cold Solder Connection*

A defect: Some of the causes may be due to insufficient heating of the part being soldered, surfaces not properly cleaned, insufficient flux, improperly tinned iron tip, or improper heat control of the iron. The required metallic luster is missing and generally the joint has the appearance of rough, piled-up solder with a granulated surface, and possessing a chalky, frosty look.

*Component*

Any electrical device, such as a coil, resistor, capacitor, generator, line or electron tube, having distinct electrical characteristics and having terminals at which it may be connected to other components to form a circuit.

*Component Side*

Component side is the side of a printed board upon which component parts are mounted. (Commonly referred to as Side 1.) (Opposite of soldered side.)

*Component Lead*

Component leads are solid, uninsulated wires protruding from the body of the component.

*Component Part*

Generally this title refers to electrical devices, such as transistors, diodes, resistors, capacitors, etc.

*Conductive Foil*

A conductive foil is a form of conductive material that covers one or both faces of the base material. (Commonly referred to as etch.)

*Conductive Pattern*

A conductive pattern is a pattern formed from any electrically conductive material, on a base.

*Conductor*

A conductor is a single conductive line forming an electrical connection between terminal areas.

*Conductor Layer*

A conductor layer is the layer of a printed board containing conductors.

*Conductor Pattern*

A conductor pattern is a pattern of conductors in a conductor layer.

*Conductor Side*

A conductor side is the side of a printed board containing the conductors. (Commonly referred to as Side 2 or soldered side.) (Opposite component side.)

*Connection*

A connection is the means by which electrical contact is made to the conductive pattern.

*Corrosive*

Chemically reactive — with ability to wear away gradually.

*Crazing*

Crazing is a condition existing in the base laminate in the form of connected white spots or crosses on or below the surface of the base laminate, reflecting the separation of fibers in the glass cloth and connecting weave intersection.

*Cross-hatching*

Cross-hatching is the breaking up of large conductive areas by use of a pattern of voids in the conductive material.

*Delamination*

Delamination is the separation of printed board material within the laminations.

*Dents*

Dents are depressions in the copper foil which do not significantly decrease the thickness of the copper foil.

*Dewetting*

Dewetting is characterized by solder not completely covering the surfaces to be bonded. Solder appears as droplets or balls having withdrawn from previously wet adjacent areas or never wetting them at all.

*Dip Soldering*

Dip soldering is a process whereby printed boards are brought in contact with the surface of a static pool of molten solder for the purpose of soldering the entire exposed conductive pattern in one operation.

*Double-Sided Board*

A double-sided board is a printed board with conductive material on both sides of the board.

*Dross*

Dross is oxide and other contaminants which form on the surface of molten solder.

*Eutectic Alloy*

An alloy of metals so proportioned that all the metals in the alloy have a specific melting point rather than a range; thus, possessing the characteristic of passing from a liquid cycle to a solid minus the intermediate plastic formation. Eutectic solder is 63% tin and 37% lead.

*Feedthrough*

See "interfacial connection".

*Fiber Exposure*

Fiber exposure is a condition in which broken glass cloth fibers are exposed in machined or abraded areas.

*Finger*

See "printed contact".

*Flux (Rosin)*

Flux is a chemically active agent that speeds the wetting process of metals with molten solder. When heated, it removes oxides; it will not remove oils, dirt, or fingerprints, only a solvent can remove the latter.

*Fractured Joint*

A joint in which the lead or part moved while the solder was solidifying. This joint will have a dull granular appearance and may have noticeable spiral cracks.

*Granular Solder*

Solder appearance with a coarse, large grain structure, lacking in metallic luster. Usually due to unclean conditions of the joining members, contaiminated solder, or excessively high temperature of the molten solder. (Also referred to as cold solder.)

*Icicle*

See "solder projection".

*Interfacial Connection*

Interfacial connection is an electrical connection between conductive patterns on opposite sides of the base. (May be an eyelet, griplet or plated through hole (PTH)).

*Jumper*

A jumper is a direct electrical connection between two points on a printed board added after the printed wiring is fabricated.

*Land*

See "terminal area".

*Legend (Marking)*

Legend is lettering or symbols on the printed board indicating part numbers, component locations, etc.

*Measling*

Measling is a condition existing in the base laminate in the form of discrete white spots or crosses below the surface of the base laminate, reflecting a separation of fibers in the glass cloth at weave intersection.

*Mounting Hole*

A mounting hole is a hole used for mechanical mounting of a printed board to the chassis or for mechanical attachment of components to the board. (Also referred to as access hole.)

*Nonwetting*

Nonwetting is a condition whereby a surface has contacted molten solder, but has had none of the solder adhere to it.

*Pad*

See "terminal area".

*Plastic Stage*

As applied to soldering, denotes the stage between liquid and solid.

*Plated-Through Hole (PTH)*

A plated-through hole is an interfacial or interlayer connection formed by deposition of conductive material on the sides of a hole through the base.

*Plating*

Plating is the process consisting of the chemical or electro-chemical deposition of metal on all or part of the conductive pattern.

*Polarizing Slot*

Polarizing slot is the slot, in the edge of a printed board, used to assure proper insertion and location in a mating connector. (Commonly referred to as the notch.)

*Pinholes*

Pinholes are small holes occurring as imperfections which penetrate into the solder.

*Preheating*

Preheating is an intermediate heating operation used to raise the temperature of the work above room temperature and thus reduce the thermal shock of an elevated temperature processing operation.

*Printed Board*

Printed board is the general term for either printed circuit or printed wiring boards.

*Printed Circuit*

A printed circuit is a pattern composed of printed wiring and printed component parts all formed on a common base.

*Printed-Circuit Assembly*

A printed-circuit assembly is a printed-circuit board on which separately manufactured component parts have been added. (Commonly called module.)

*Printed-Circuit Board*

A printed-circuit board is a completely processed conductive pattern.

*Printed Contact*

A printed contact is that portion of printed wiring used for the purpose of providing electrical connection by pressure contact and is usually gold plated.

*Printed Edge Board Contacts*

Printed edge board contacts are patterns extending to the edge of a printed board intended for mating with external contacts (usually gold plated).

*Printed Wiring*

Printed wiring is a conductor pattern used for the purpose of providing point to point electrical connections.

*Printed-Wiring Assembly (Module)*

A printed-wiring assembly is a printed-wiring board on which separately manufactured component parts have been added.

*Printed-Wiring Board*

A printed-wiring board is a completely processed conductor pattern.

*Residue*

Excessive substance remaining after soldering, such as flux or oil.

*Rosin Connection*

The rosin solder connection (bond) is a layer of solidified flux; an interface between the conductors having no metallic or electrical continuity resulting in a high resistant condition with a low strength factor. The possibility does exist that all or part of the connection is held together with rosin flux in lieu of a good bond with molten solder. The "carry-to" technique of soldering can produce these conditions.

*Scorch*

To burn a surface so as to change its color and texture.

*Single-Sided Board*

A single-sided board is a printed board with conductors on one side.

*Side 1*

Side 1 is the component side of the printed circuit board/assembly (opposite the soldered side.)

*Side 2*

Side 2 is the soldered side of the printed circuit board/assembly (opposite the component side.)

*Solder*

Ordinary soft solder is a fusible alloy consisting of essentially tin and lead, and used for the purpose of joining together two or more metals at temperatures below their respective melting points. Rosin core type SN60 (60% tin, 40% lead) is normally used for soldering electronic assemblies. Solders which melt readily are soft solders, others fusing at a red heat are hard solders.

*Solderability*

Solderability is the property of a metal surface which allows it to be wetted by solder.

*Solder Impurities*

The trace metals that appear in a solder bath during usage.

*Solder Splashes*

Drops of solder in areas that should be free of solder; a most undesirable condition.

*Solder Projection*

Solder projection is undesirable protrusion from a solidified solder joint or coating commonly called icicle.

*Supported Hole*

A supported hole is a hole in a printed board containing plating, eyelets, standoff terminals, etc.

*Terminal Area*

A terminal area is that portion of a printed circuit or wiring used for making electrical connections to the conductive pattern or component.

*Terminal Hole*

A terminal hole is a hole within a terminal area.

*Terminal Pad*

See "terminal area".

*Through Connection*

See "interfacial connection".

*Tinning*

Tinning is a solder coating of the conductive paths and terminals, primarily for minimizing in-process oxidation and enhancing solderability.

*Twist*

Twist is bending or curving distortion from a true or plane surface, in a direction parallel to a diagonal between two opposite corners of the sheet/printed circuit board/module assembly.

*Unsupported Hole*

An unsupported hole is a hole containing no conductive material, within a terminal area.

*Warp*

Warp is the deviation from flatness of a board characterized by a roughly cylindrical or spherical curvature such that, if the board is rectangular, its corners or edges are in the same plane as the major surfaces of the board.

*Wave Soldering*

Wave soldering is a process whereby printed boards are brought in contact with the surface of continuously flowing circulated solder.

*Weave Exposure*

Weave exposure is a surface condition in which the unbroken woven glass cloth is not uniformly covered by resin.

*Weave Texture*

Weave texture is a surface condition in which the unbroken fibers are completely covered with resin but yet exhibits the definite weave pattern of the glass cloth in the outer surface of the base.

*Wetting*

Wetting is the free flow and spreading of solder on conductive paths and terminals to form an adherent bond.

*Whisker*

A whisker is a slender acicular metallic growth which occurs after the printed board has been manufactured.

*Wicking*

The action of drawing up solder through capillary action.

## IDENTIFICATION/MARKING

*General*

All markings shall be legible, uniform in height, size, and of a color that is in contrast to the finish on which it is applied.

*Identification*

All identifying markings such as assembly number, assembly date code, circuit schematic revision level and module type shall be complete and readable. Filled letters and numbers shall be considered acceptable only if readable.

ACCEPTABLE (Preferred)
Marking is very distinct.

ACCEPTABLE (Minimum)
Marking is slightly smudged, but readable.

UNACCEPTABLE
Marking is unreadable.

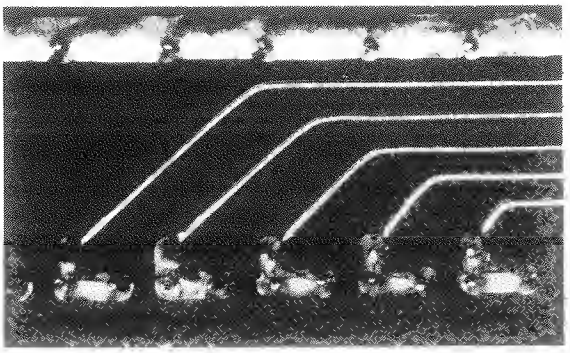
BURNT/SCORCHED

*Burnt*

Printed circuit boards that are burnt are not acceptable.

*Scorched*

Printed circuit boards that are subjected to heat severe enough to cause large areas of discoloration and surface roughness in the process of fabrication or assembly shall be considered unacceptable.



ACCEPTABLE (Preferred)
Printed circuit does not exhibit discoloration from severe heat.

(BLANK)

ACCEPTABLE (Minimum)
There are no minimum acceptable conditions for burnt or scorched boards.

UNACCEPTABLE
The printed circuit board exhibits burns, delamination, and discoloration from severe heat.

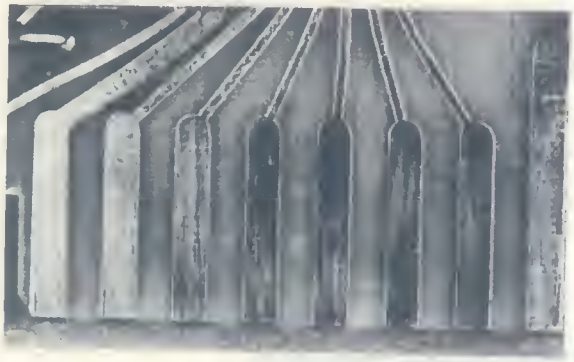
## PLATING ON CONTACT FINGER

*Damage*

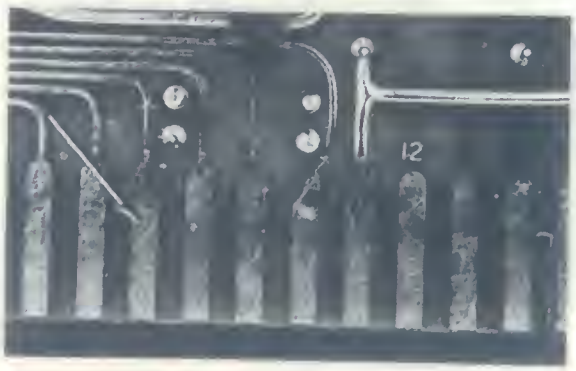
Scratches, chipping, peeling, or mars that extend into the base material and expose the copper are not acceptable.

*Plating–Bridging*

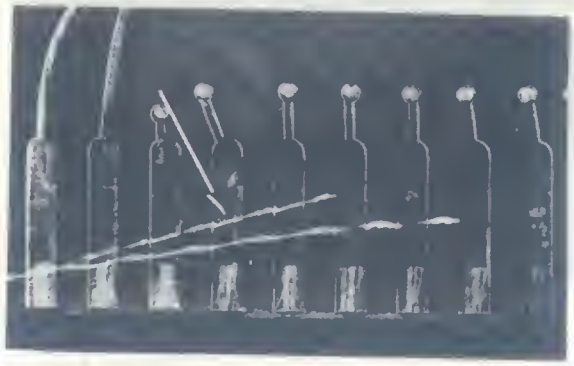
Plating that is bridging the contact fingers at the beveled edge of the contact fingers is not acceptable.



ACCEPTABLE (Preferred)
No damage or scratches on the contact fingers.



ACCEPTABLE (Minimum)
Damage is slight and does not extend into the base material and expose copper.



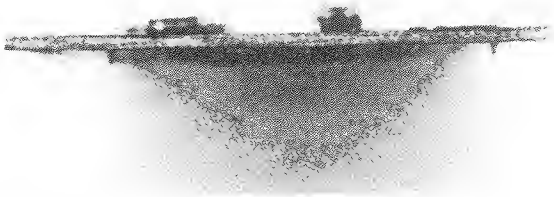
UNACCEPTABLE
Deep scratches occur in the plating, extend into the base material and expose copper.

*NOTE:* For critical contact area of fingers use Engineering Specification A-SP-7665051-0-0 and critical contact area gages #9305674 and #9305673 to determine acceptability.

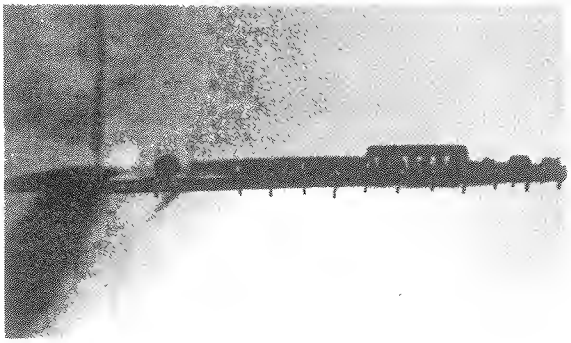
TWIST

*General*

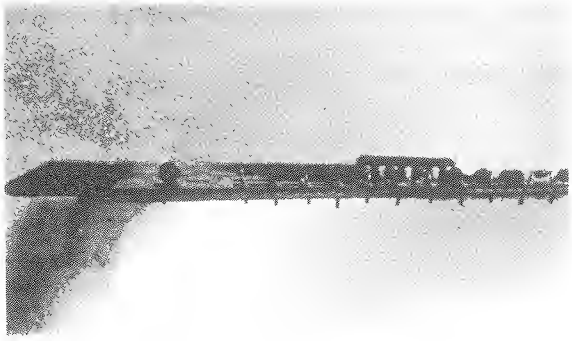
The manufacturing processes shall not cause twist to exceed 0.007 inch/inch across the diagonal of the printed circuit board.



ACCEPTABLE (Preferred)
No twist in printed circuit assembly.



ACCEPTABLE (Minimum)
Printed circuit assembly has a maximum twist of 0.007 inch/inch.

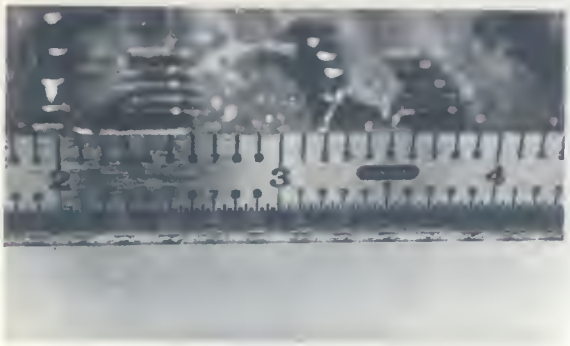


UNACCEPTABLE
Printed circuit assembly has twist greater than 0.007 inch/inch.

## WARPAGE AND BOW (WIDTH OF MODULE)

*General*

The manufacturing processes shall not cause warpage to exceed 0.007 inch/inch across the printed circuit board assembly.



ACCEPTABLE (Preferred)
Printed circuit assembly contact edge without warpage. (Scale for reference only.)

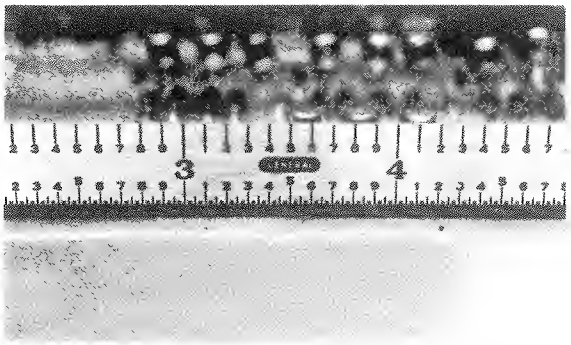
ACCEPTABLE (Minimum)
Printed circuit assembly contact edge with maximum warpage, 0.007 inch/inch.

UNACCEPTABLE
Printed circuit assembly contact edge with warpage greater than 0.007 inch/inch.

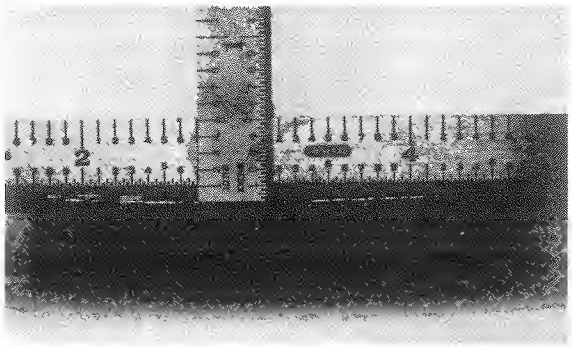
## WARPAGE AND BOW (LENGTH OF MODULE)

*General*

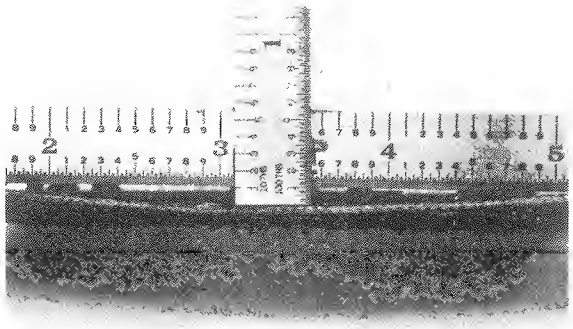
The manufacturing processes shall not cause warpage of the printed board area to exceed 0.007 inch/inch.



ACCEPTABLE (Preferred)
Printed circuit assembly has no warpage. (Scale for reference only.)



ACCEPTABLE (Minimum)
Printed circuit assembly has maximum warpage of 0.007 inch/inch.



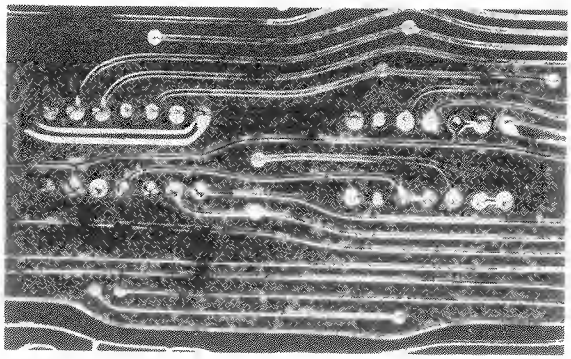
UNACCEPTABLE
Printed circuit assembly has warpage greater than 0.007 inch/inch.

## MEASLING

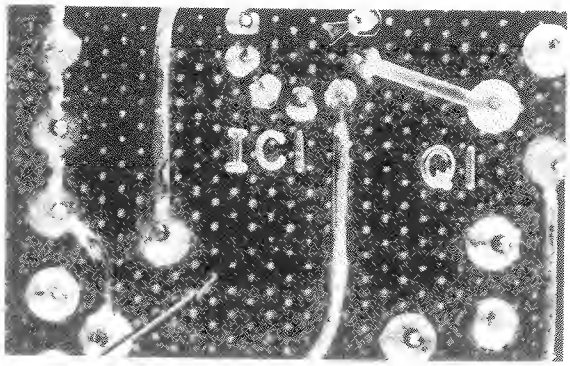
*General*

Measling is described as a condition existing in the base laminate in the form of discrete white spots or crosses below the surface of the base laminate, reflecting a separation of fibers in the glass cloth at the weave intersection.

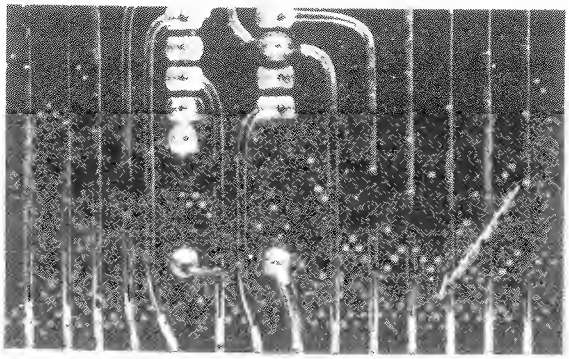
Measling is not electrically degrading and is generally acceptable. Only in extreme cases shall measling be considered unacceptable.



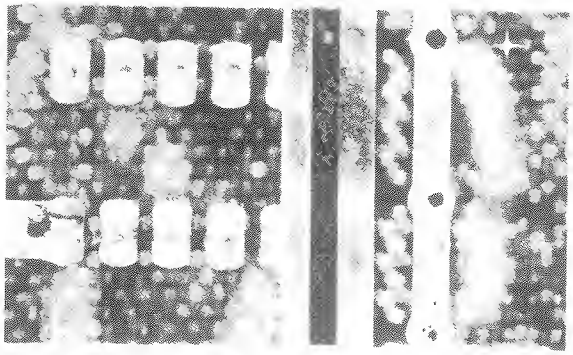
ACCEPTABLE (Preferred)
No weave exposure or areas of delamination.




ACCEPTABLE
Weave exposure not adversely affecting the mechanical or electrical properties of the base laminate.



ACCEPTABLE (Minimum)
Areas of weave exposure accompanied by areas of measling.



UNACCEPTABLE
Severe measling and delamination are in evidence.

## MEASLING/CRAZING

*General*

Crazing is described as a condition existing in the base laminate in the form of connected white spots or crosses on or below the surface of the base laminate, reflecting the separation of fibers in the glass cloth and connecting weave intersections.

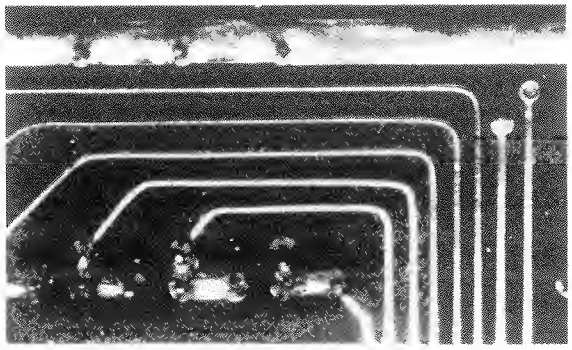
*Measling Bridging Conductors*

A single measle bridging two printed circuit conductors is acceptable.

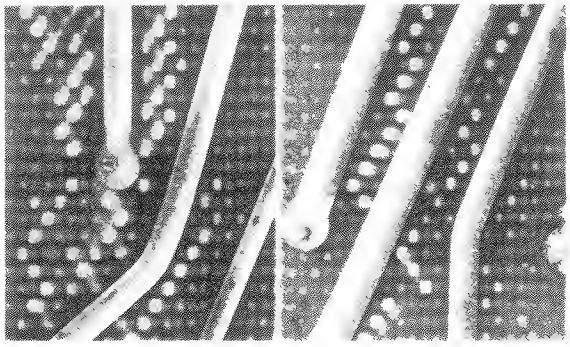
*Lifted Conductor or Pad*

Any degree of measling/crazing that causes pads/traces to lift away from the printed circuit board surface is unacceptable.

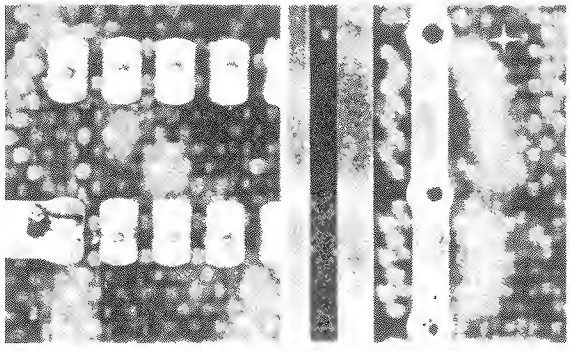
The degree of measling/crazing larger than a single intersection and an obvious delamination that is bridging conductors is unacceptable.



ACCEPTABLE (Preferred)
No measling, crazing, or delamation.



ACCEPTABLE (Minimum)
Measling bridging two conductors.

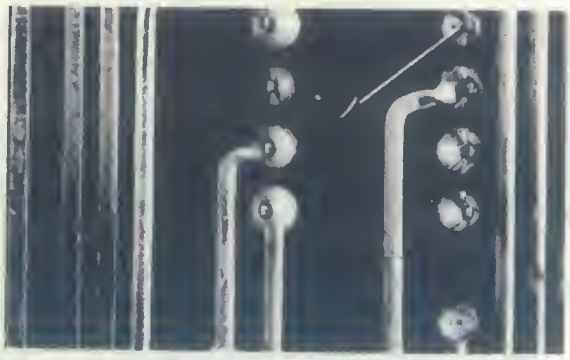


UNACCEPTABLE
Measling and crazing with delamination.

## DELAMINATION

*General*

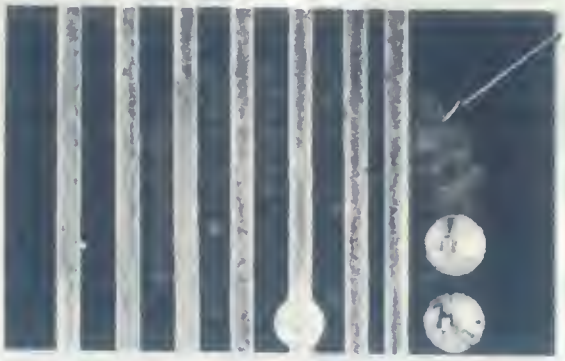
This condition is recognized by the blistering effect in the base laminate and any degree of blistering shall be considered unacceptable.



(BLANK)

ACCEPTABLE (Preferred)
No blistering or separation between fiber layers.

ACCEPTABLE (Minimum)
There are no minimum acceptable conditions of delamination.



UNACCEPTABLE
Blistering is in evidence in the laminate.

## LIFTED PADS/CONDUCTORS

*Pads without Attached Conductors*

Shall be considered acceptable when a maximum of three (3) lifted pads occurs for every ten (10) square inches of the board.

Pads lifted less than 50% in area and soldered, shall be considered acceptable when they exhibit good wetting of component lead and pad.

*Pads with Attached Conductors*

Shall be considered unacceptable when lifted.

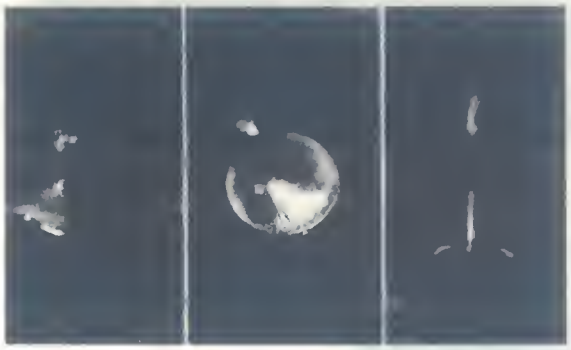
*Conductors*

Shall be considered unacceptable when lifted.

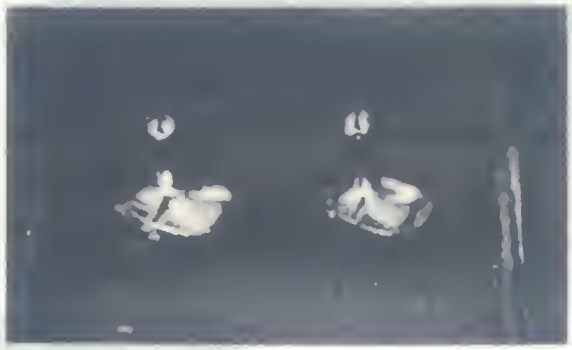
*Missing Pads without Attached Conductors*

Shall be considered acceptable when they do not exceed the maximum of 10% of the number of holes in a component pattern (example: one missing pad in 14 pin I.C. pattern).

*NOTE:* "Attached conductors" shall include conductors attached on component side (side 1) although pad in question is on soldered side (Side 2).



ACCEPTABLE (Preferred)
No lifted pads or conductors.



ACCEPTABLE (Minimum)
Lifted pads maximum of three per ten (10) square inches of board.

UNACCEPTABLE
Lifted pad on interfacial hole, lifted pad with attached conductor, lifted conductor.

## CONTAMINATION/CLEANING

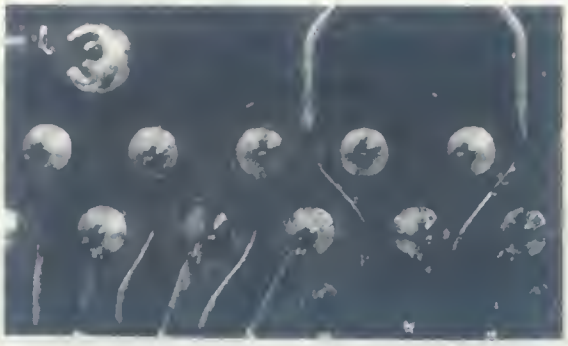
*Contamination*

Contamination by any foreign material that may affect surface resistivity of the printed circuit assembly is not acceptable.

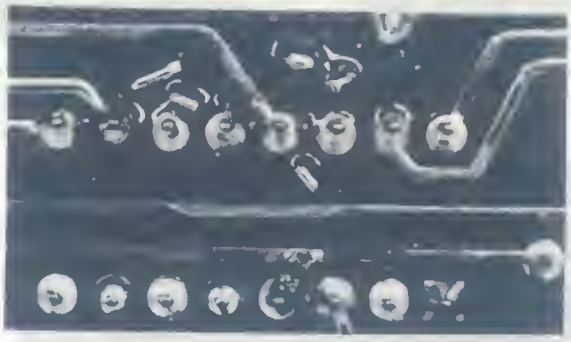
Foreign material shall be removed by thorough cleaning. Particular care shall be taken to eliminate the following:

(a) Metal chips
(b) Filings
(c) Clippings
(d) Wire strands
(e) Flux
(f) Rosin flakes
(g) Loose terminals
(h) Solder balls
(i) Solder splatter
(j) Residues
(k) Silicon (eyeglass cleaning paper)
(l) Salt (food residue)

ACCEPTABLE (Preferred)
Board is clean of residues or contaminants.



ACCEPTABLE (Minimum)
Board is clean except for white residue.



UNACCEPTABLE
Board has contaminate solder, wire clippings, solder balls, imbedded in the flux.

## COMPONENTS

*Assembly*

Printed circuit boards are primarily used to interconnect various types and configurations of components to make a functional electronic device.

*Mounting*

The manner in which components are mounted to the printed circuit board is of critical importance. Most conventional components such as capacitors, resistors and diodes are generally mounted parallel to the printed circuit board surface. Usually, the only fastening holding components to the printed circuit board are the leads themselves. Components should be mounted as close to the board as practical unless additional support is required or component is raised for heat dissipation or other reasons.

*Damage*

Components that show visible evidence of physical degradation of the body, leads, seal, and markings shall not be used in printed circuit board assemblies (modules).

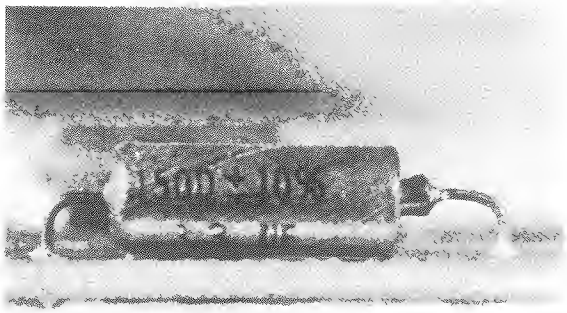
COMPONENT LEADS

*Bend Location*

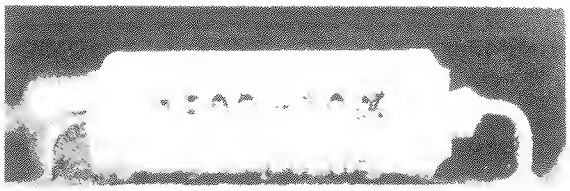
The lead should extend approximately straight out from the body of the component a minimum of 1/16 (0.062) inch prior to the start of the bend and pass through the board perpendicular to the board surface.

*NOTE:* The end of the body is defined to include any coating meniscus, solder seal, solder or weld bead (as on tantalum capacitors), or any other extension.

The lead may exhibit a maximum bend of five (5) degrees at the body.



ACCEPTABLE (Preferred)
Lead bend at 1/8 (0.125) inch from body of component.



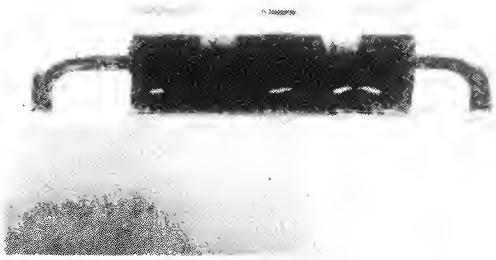
ACCEPTABLE (Minimum)
Lead bend at 1/16 (0.062) inch from body of component.

UNACCEPTABLE
Lead is bent at the body of the component, causing a fracture at the seal.

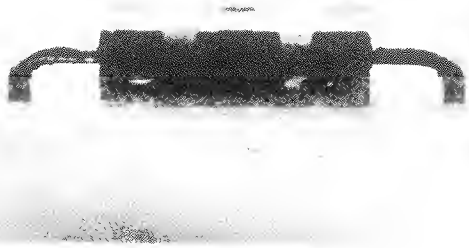
## COMPONENT BEND RADIUS

*General*

The minimum inside bend radius of a component lead shall be one (1) lead diameter. The maximum bend radius shall be 1/8 (0.125) inch.



ACCEPTABLE (Preferred)
Bend radius of the lead is two wire diameters.



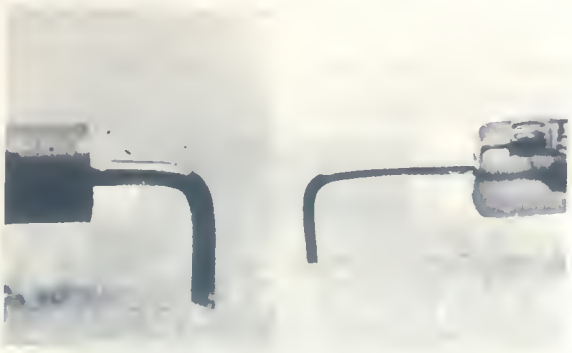
ACCEPTABLE (Minimum)
Bend radius of the lead is a minimum of one lead diameter.

UNACCEPTABLE
Bend radius is less than one lead diameter.

## COMPONENT DOUBLE BENDS

*General*

Component leads shall not exhibit a double bend caused by forcing the component to be flush on the board after mounting. Component leads shall not be bent unnecessarily.



ACCEPTABLE (Preferred)
Component lead extends straight out from component body.

ACCEPTABLE (Minimum)
Component lead has a bend less than five (5) degrees at the body of the component.

UNACCEPTABLE
Component body was pushed down causing a double bend on the lead more than five (5) degrees.

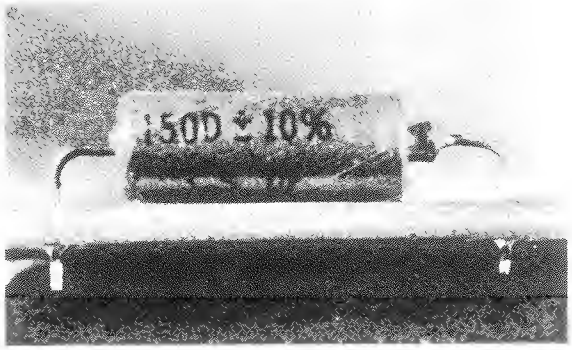
## COMPONENT LEAD LENGTHS

*General*

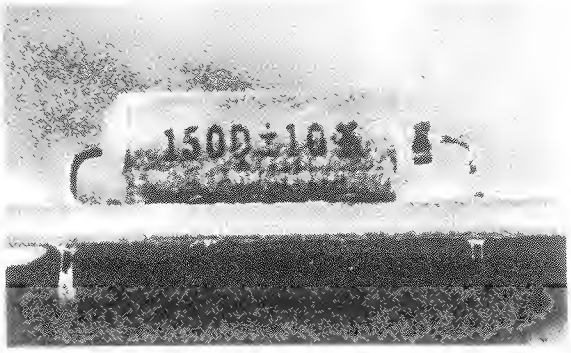
The minimum lead length shall permit a correctly mounted component to extend through the printed circuit board 1/32 (0.031) inch and a maximum of 1/16 (0.062) inch.

*Preformed Leads*

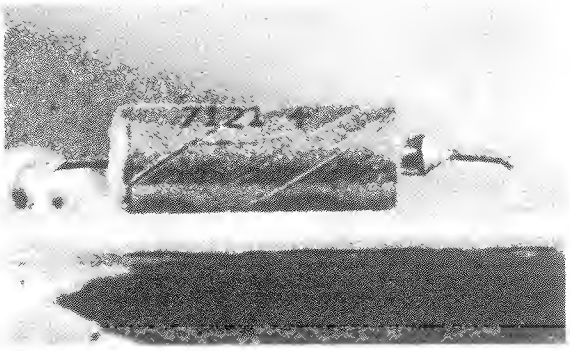
Preformed leads shall be formed to meet the minimum lead length, maximum lead length, and the maximum component height requirements.




ACCEPTABLE (Preferred)
Leads extend through the printed circuit board 1/16 (0.062) inch.




ACCEPTABLE (Minimum)
Leads extend through the printed circuit board a minimum of 1/32 (0.031) inch and a maximum of 1/16 (0.062) inch.



UNACCEPTABLE
Lead is less than 1/32 (0.031) inch through printed circuit board. Lead is greater than 1/16 (0.062) inch through printed circuit board.

*NOTE:* Use Gages #9405111 and #9405078 for soldered side projections.

## COMPONENT LEAD DAMAGE

*General*

Component leads that are nicked, cut, dented, flattened, or deformed where the cross sectional area of the lead has been reduced more than twenty five percent (25%), are unacceptable.

*NOTE:* A nick is a partial severence of the conductor.

ACCEPTABLE (Preferred)
No lead damage.

ACCEPTABLE (Minimum)
Slight deformation less than twenty five percent (25%) of lead diameter.

UNACCEPTABLE
Damaged leads affecting more than twenty five percent (25%) of lead diameter.

## COMPONENT LEAD WELDS

*General*

Lead welds that are cracked, broken or have voids are not acceptable.

*Plating*

Plating on leads that are obviously porous, pitted, incomplete or peeling is unacceptable.

ACCEPTABLE (Preferred)
No evidence of lead damage or degradation.

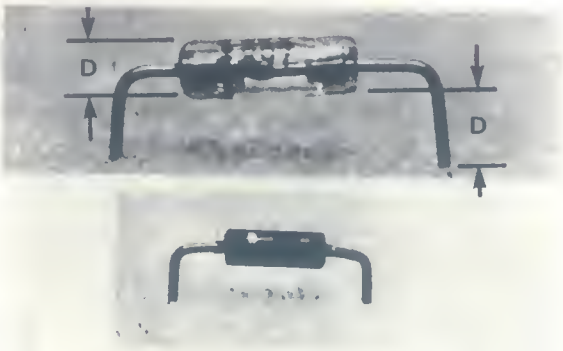
ACCEPTABLE (Minimum)
Line crack at weld, tarnished silver leads, rough textured plating.

UNACCEPTABLE
Gaps and cracks in weld, rusted or oxidized leads and pitted, peeling or voids in plating are unacceptable.

## GLASS PACK COMPONENT MOUNTING

Component leads shall have sufficient lead forming to allow for contraction and flexure of printed circuit board and the physical stress that may be encountered during assembly.

ACCEPTABLE (Preferred)
Leads formed to provide adequate stress relief. No damage to glass body.




ACCEPTABLE (Minimum)
Component not flat on board to maximum height of one (1) component diameter (D). Leads have minimum lead forming for stress relief (conforms to 5° maximum bend out of component body).

UNACCEPTABLE
Component not flat on board and exceeds maximum of one (1) component diameter. Chips, cracks and other component damage is visible. Leads are bent toward board with no stress relief (exceeds 5° maximum bend out of component body).

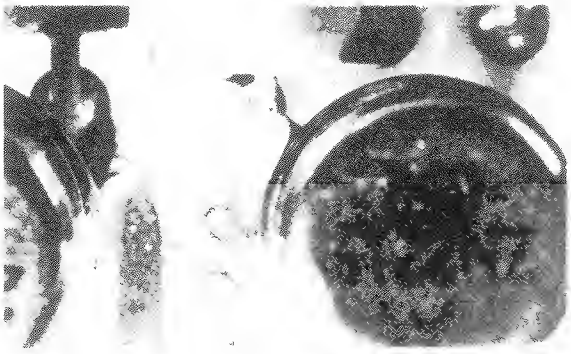
## COMPONENT LEAD SLEEVING

*General*

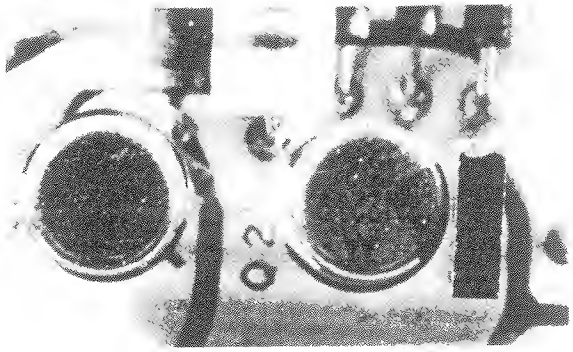
Component leads shall be insulated if they are within 1/32 (0.031) inch of conductor surface or over 3/8 (0.375) inch in length from the component body to bend radius. Large supported or anchored components do not fall in this category.

Insulation sleeving may be flexible plastic or heat-shrinkable tubing. Insulation sleeving shall be free of splits, tears, cuts and burns.

ACCEPTABLE (Preferred)
Lead is close to transistor case and is protected by sleeving.



ACCEPTABLE (Minimum)
Lead is protected by sleeving which is short but has covered enough of lead to prevent shorting.



UNACCEPTABLE
Unprotected lead in danger of shorting.

## COMPONENT LEAD DRESS

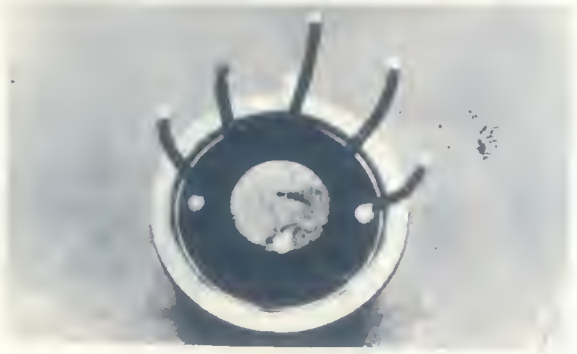
*General*

Integrated Circuit (IC) Pack (Typical Case Style also applies to transistors)

Multilead components that are twisted on their leads are unacceptable.

Multilead components shall have their preformed leads radiate out symetrically from the center so the orientation tab is correct.

Multilead components shall not have their leads bent so that the flashover distance from the lead to the body is reduced.



ACCEPTABLE (Preferred)
Leads radiate straight out symetrically from center.

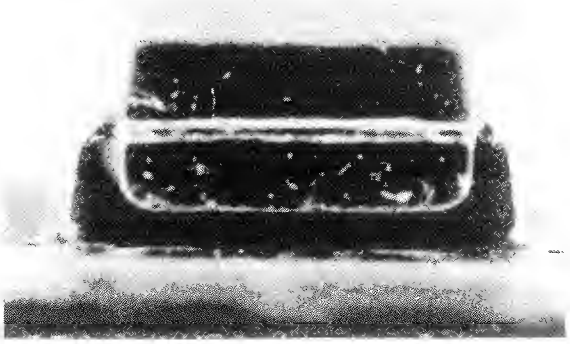
ACCEPTABLE (Minimum)
Leads radiate out symetrically – tab orientation maintained.

UNACCEPTABLE
Twisted, crossed leads which do not allow correct tab orientation are unacceptable.

## COMPONENT LEAD DRESS

*General (Dual-In-Line (DIP) Package)*

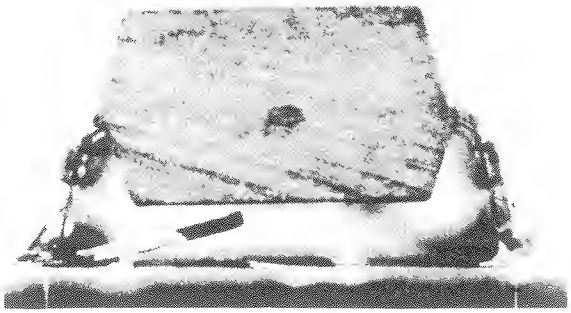
When a dual-in-line packaged integrated circuits are used, care should be exercised to make sure all legs are inserted into their respective holes and not bent under the IC pack.



ACCEPTABLE (Preferred)
All legs of the dual-in-line pack are in their respective holes.

(BLANK)

ACCEPTABLE (Minimum)
There are no minimum acceptable conditions on lead dress of DIP leads.



UNACCEPTABLE
Dual-in-line pack leg bent under pack.

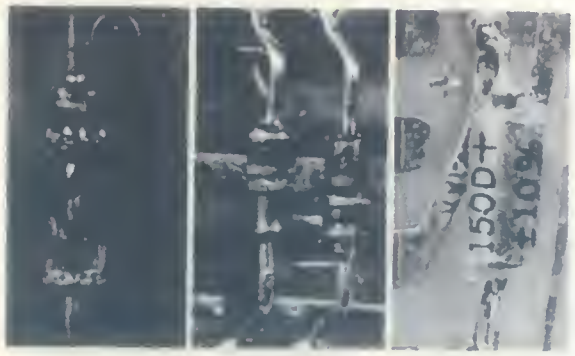
## POLARIZED COMPONENTS

*General*

All polarized components shall be mounted with the polarity as specified.

*Marking*

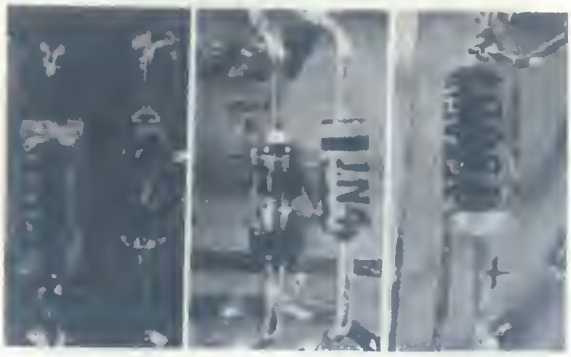
Marking that is not visible on the component body *after* mounting shall not be considered cause for rejection.




ACCEPTABLE (Preferred)
Correctly installed polarized components.

(BLANK)

ACCEPTABLE (Minimum)
There are no minimum acceptable conditions for polarity.

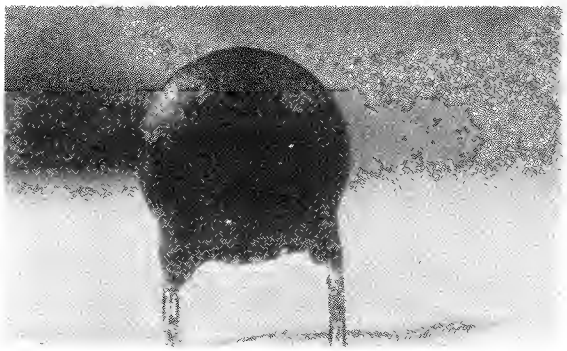


UNACCEPTABLE
Polarity reversed with polarity on the printed circuit board.

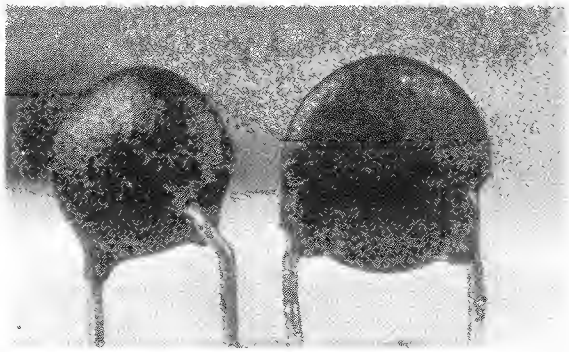
COMPONENT BODY

*General*

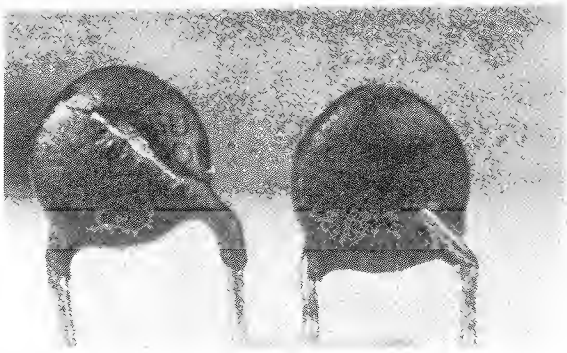
Chipped insulation on component body, such as resistors, transistors, capacitors, micrologic IC's, etc., is not acceptable if the damage extends into the electrical portion of the component.



ACCEPTABLE (Preferred)
No damage to component body.



ACCEPTABLE (Minimum)
Small chips off corners or meniscus – not into body of component.



UNACCEPTABLE
Chips broken off the component body exposing the internal construction.

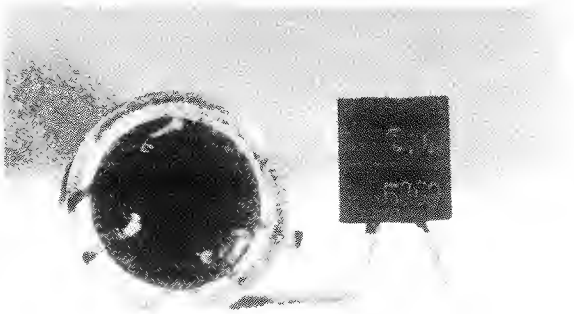
*NOTE:* Meniscus shall not protrude into circuit board access hole in such a manner as to form an air seal, plug or otherwise affect the solder flow.

## HERMETICAL SEALS

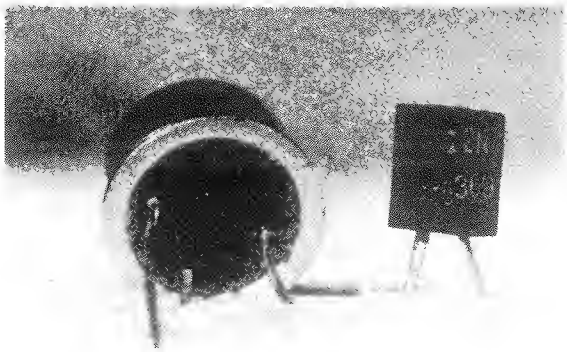
*General*

Hermetically sealed components such as miniature relays, glass sealed capacitors, diodes, transformers, power transistors, crystals, reed relays, etc., shall not have seals that are chipped, cracked, or grazed.

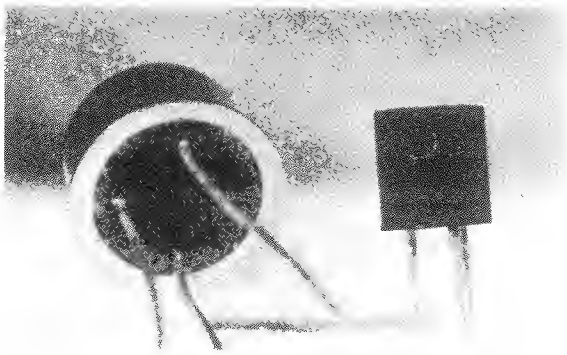
The coating on leads (meniscus) shall not be removed beyond where the lead enters the body.



ACCEPTABLE (Preferred)
No evidence of seal damage.



ACCEPTABLE (Minimum)
Slight crack or pin hole next to lead that doesn't endanger the seal.



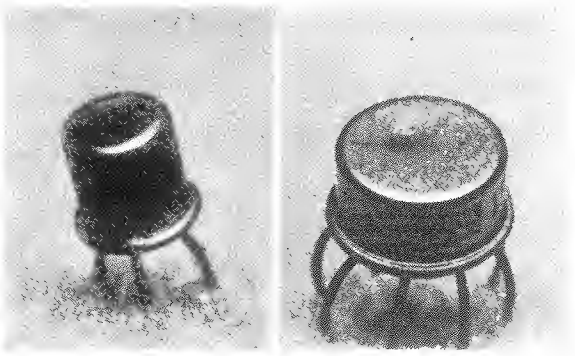
UNACCEPTABLE
Cracked or broken seals – voids, holes.

DENTED/GOUGED COMPONENT

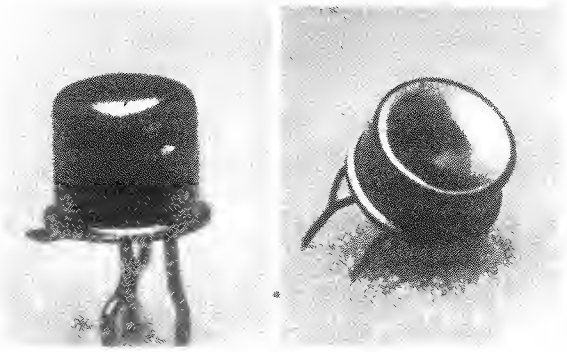
*General*

Metal can components which exhibit obvious dents/gouges are unacceptable.

ACCEPTABLE (Preferred)
No marks or damage.



ACCEPTABLE (Minimum)
Slightly concave top. Small machine impression.



UNACCEPTABLE
Obvious dents, sharp impressions, cuts, and gouges are not acceptable.

## COMPONENT MOUNTING

*Height*

The maximum height of any component shall not exceed the requirements of the applicable Engineering Drawing. Vertically mounted components shall not be bent over to meet height requirements. (Insulated component maximum height is 3/8 (0.375) inch and uninsulated component maximum height is 11/32 (0.344) inch).

*Horizontal Placement*

Horizontal placement of axial lead supported components should be mounted so their axis is parallel to the printed circuit board. The body should be in direct contact with the printed circuit board.

ACCEPTABLE (Preferred)
All component heights fall within the maximum allowable height as specified.

ACCEPTABLE (Minimum)
The average height of any one component falls within the maximum height limit.

UNACCEPTABLE
Any component which has a height greater than the specified maximum is unacceptable. Components bent over to meet height requirements are unacceptable.

*NOTE:* Use gages #9405111 and #9405078 for component height.

## RAISED COMPONENTS

*General*

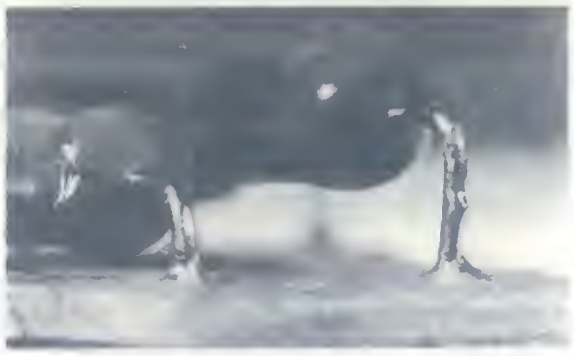
Components required to be raised shall be raised a minimum of 1/32 (0.031) inch from the printed circuit board. The component may be raised to a maximum of 3/16 (0.187) inch, but must not exceed the maximum component height requirement of 3/8 (0.375) inch.

*High Wattage Components*

High wattage components shall be raised from the surface of the printed circuit board.

ACCEPTABLE (Preferred)
Raised components mounted 1/16 (0.062) inch from board surface.

ACCEPTABLE (Minimum)
Raised component at maximum or minimum dimension from the board.



UNACCEPTABLE
Any raised component mounted above or below the required range is unacceptable.

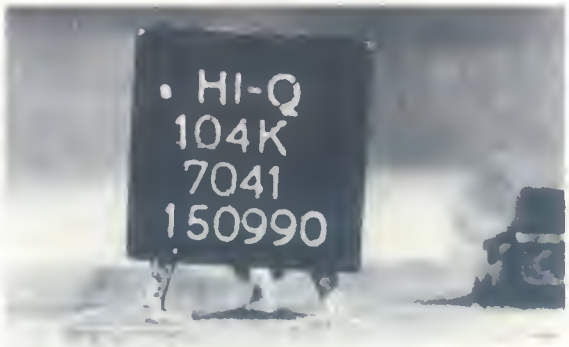
*NOTE:* Use Gages #9405111 and #9405078 to check for component height acceptability.

## RADIAL LEAD COMPONENTS

*General*

When solder joints are made on the component side of the board, the component shall be raised a minimum of 1/32 (0.031) inch.


ACCEPTABLE (Preferred)
Radial lead component raised 1/32 (0.031) inch off the board minimum.



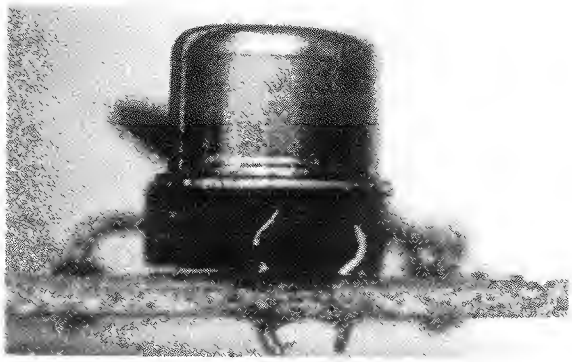

ACCEPTABLE (Minimum)
Radial lead component raised off the board 1/16 (0.062) inch maximum.


UNACCEPTABLE
Radial lead component flat on board surface.

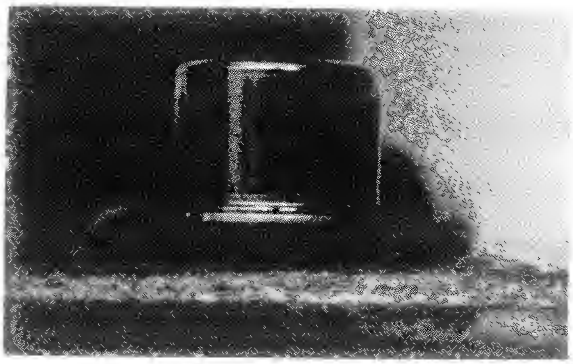
COATED OR SEALED COMPONENTS – NO SPACER

*General*

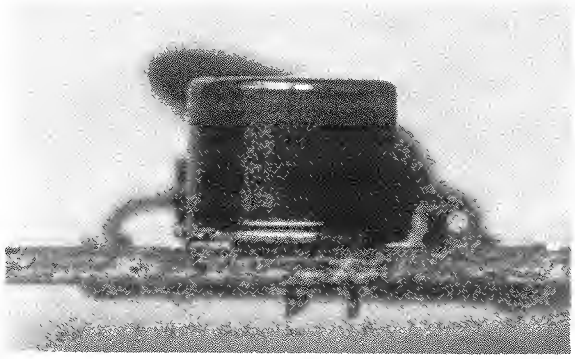
When a transipad is *not* used, the component shall be mounted with the installed height a minimum of 1/16 (0.062) from the surface of the printed circuit board.



ACCEPTABLE (Preferred)
Components mounted up off the board.



ACCEPTABLE (Minimum)
Component mounted a minimum of 1/16 (0.062) inch from the board surface.

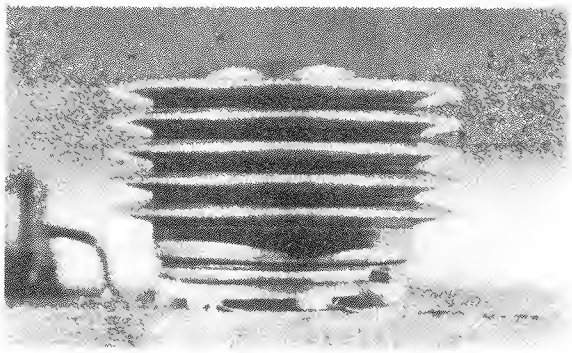


UNACCEPTABLE
Components mounted flat, in contact with the board are unacceptable.

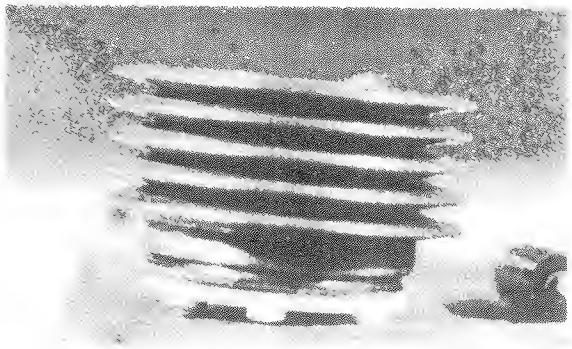
COATED OR SEALED COMPONENTS – WITH SPACER

*Transipad*

When a spacer (transipad) is used the pad shall be flush with the board and the bottom of the transistor.



ACCEPTABLE (Preferred)
Both transistor and transipad are flat on the board.



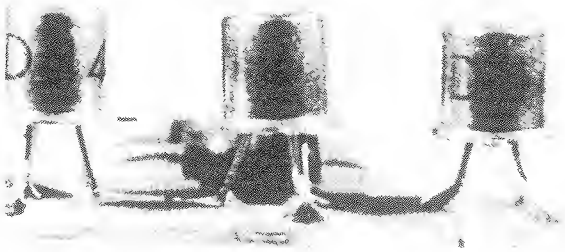
ACCEPTABLE (Minimum)
Slight gap between transistor, transipad, and board.

UNACCEPTABLE
Inverted transipad, excessive gap between transistor, transipad, and board.

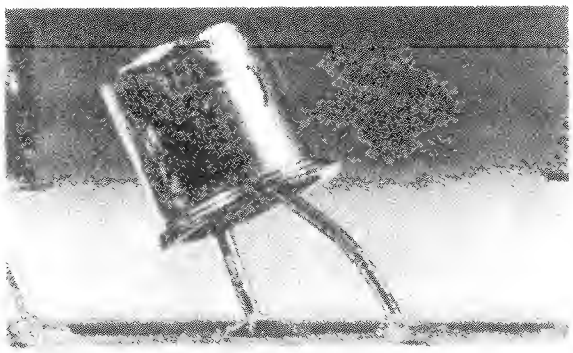
## COMPONENTS

*General*

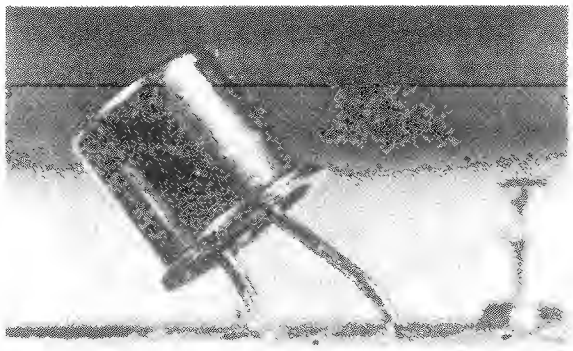
Components with three or more leads shall not have their vertical axis deviate from the perpendicular of the printed circuit board surface by more than twenty degrees (20°).



ACCEPTABLE (Preferred)
Multilead components are mounted vertically.



ACCEPTABLE (Minimum)
Multilead components mounted less than twenty degrees (20°) off the vertical axis.

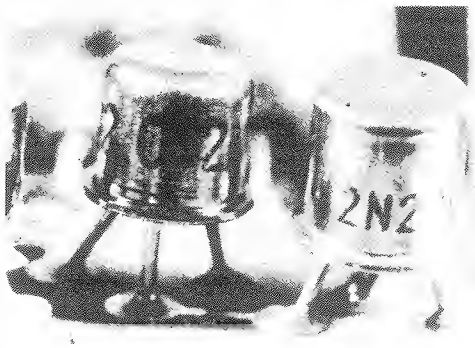


UNACCEPTABLE
Multilead components mounted with a deviation from the vertical greater than twenty degrees (20°) are unacceptable.

## SEPARATION DISTANCE (SHORTING AND FLASHOVER)

*General*

Unless otherwise specified the distance between metallic non-connected component leads, traces, ground planes, hardware, etc., shall not be less than 0.020 inch. This is a workmanship parameter to prevent the shorting of bendable or movable component leads, hardware, etc., and does not apply to fixed non-movable design distances such as printed circuit board conductor separation, etc.



ACCEPTABLE (Preferred)
Metal components are straight and maintain a distance of 1/32 (0.031) inch or more.

ACCEPTABLE (Minimum)
Metal components spearated by a minimum of 0.020 inch.

UNACCEPTABLE
Metal components are touching each other (less than 0.020 inch clearance).

## PRINTED CIRCUIT BOARDS – SOLDERING

*General*

The external appearance can be used to evaluate the quality of the solder joint. Visual inspection of the solder joint can be made with the unaided eye or magnification up to 10 power, when necessary. An inspectable solder joint makes it possible and feasible to recognize visually the parameters indicating quality such as wetting, proper geometric configuration, and good workmanship.

*Wetting*

Wetting or alloying has occurred when the solder has spread out into a thin film on the solderable surface with the fillet feathering into the surface. Conversely, a nonwetting condition will result in the solder forming a ball or bead on the surface (as a water bead forms on a well-waxed surface).

*Geometric Configuration*

The geometric configuration includes such items as length of lead in the joint area, direction of lead and contacts, the amount of wire wrap around the terminal, the depth of insertion of the terminals in holes and plated-through holes, the height of solder rise in a plated-through hole, etc.

*Workmanship*

Smooth surface which indicates the joint was heated sufficiently to allow the solder to have good fluidity. The smooth surface also indicates that no appreciable metallic or non-metallic impurities were present. Surfaces should generally be bright and shiny.

*Inspectability*

The contour of the joint members should be visible in most cases. While extra solder obscuring the joint does not necessarily indicate a nonwet joint, it does prevent visual inspection and thus prevents the use of the most valuable inspection criteria.

> *NOTE:* Where components are mounted in such a manner which prevents joint inspectability, it shall not be cause for rejection.

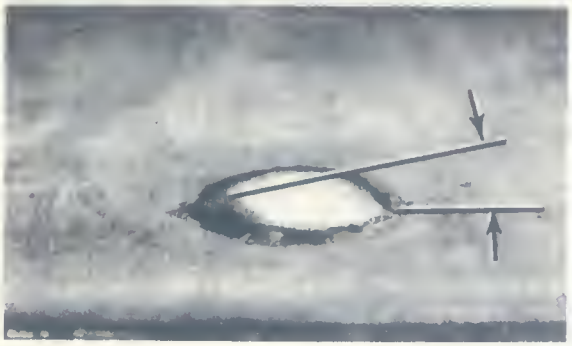
## WETTING

*General*

The wetting action of solder occurs when the liquified solder has spread out into a thin film, covering the solderable surface.

The degree of wetting can be determined by the wetting angle. The wetting angle is the angle formed between the solder and the material to be soldered.

*NOTES:* Shown below are examples of what occurs to a ball of solder at various degrees of wetting on the base metal. Page 4-54 shows a practical example of the various degrees of wetting.



ACCEPTABLE (Preferred)
Good wetting action has occurred. The wetting angle is less than 15 degrees.

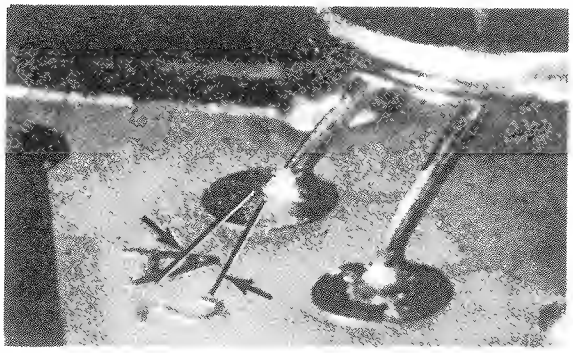
ACCEPTABLE (Minimum)
Partial wetting has occurred, the wetting angle is less than 90 degrees.

UNACCEPTABLE
Non-wetting has occurred, the wetting angle is greater than 90 degrees.

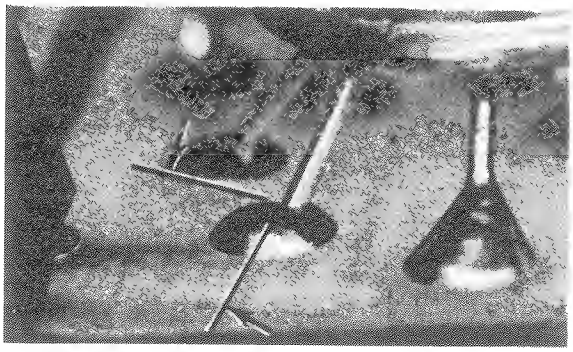
NONWETTING

*General*

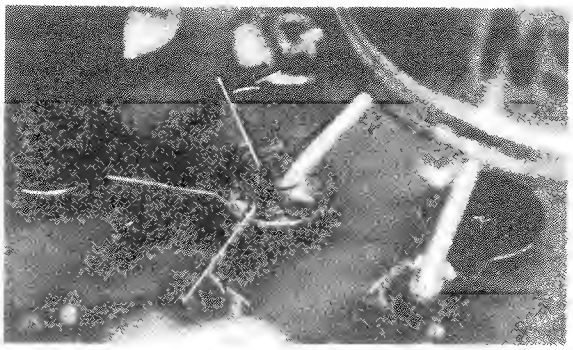
Nonwetting is characterized by the fillet not feathering into the surface to be bonded. The wetting angle will be greater than 90 degrees.



ACCEPTABLE (Preferred)
Good wetting of lead and pad, wetting angle less than 15 degrees.



ACCEPTABLE (Minimum)
Partial wetting has occurred, wetting angle is greater than 15 degrees but less than 90 degrees.



UNACCEPTABLE
Nonwetting of the lead, wetting angle is greater than 90 degrees to the lead.

## COLD SOLDER JOINT

*General*

A cold solder joint has a rough, chalky or crystallized, dull piled-up appearance. The interface of the solder with component lead does not have a smooth fillet.

(BLANK)

ACCEPTABLE (Preferred)
Good solder fillet adhering to both the lead and pad. Solder joint has been heated sufficiently to have good fluidity.

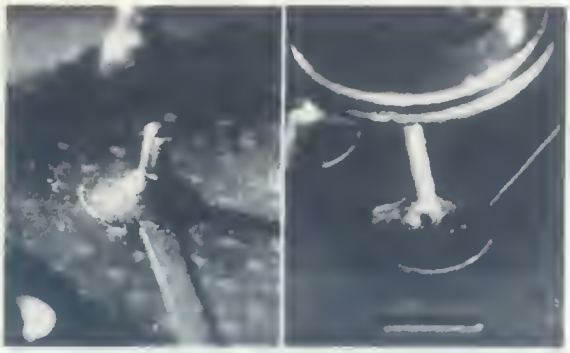
ACCEPTABLE (Minimum)
There are no minimum acceptable conditions for cold solder connections (joints).

UNACCEPTABLE
The solder has not bonded the lead to the pad. The appearance is dull and chalky.

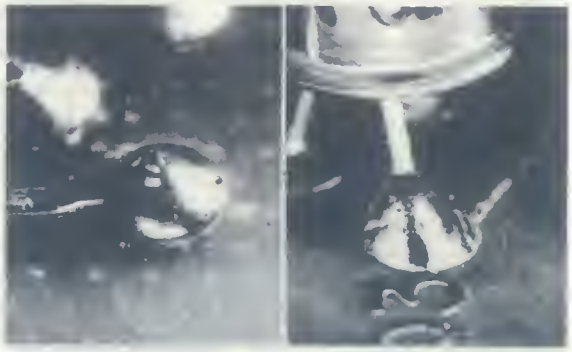
## EXCESSIVE SOLDER

*General*

Excessive solder is identified by the solder joint being completely obscured by solder. A solder joint with excess solder is uninspectable.



ACCEPTABLE (Preferred)
Good solder fillet adhering to both lead and pad with complete coverage.



ACCEPTABLE (Minimum)
Evidence of lead and pad wetting visible.

UNACCEPTABLE
Solder is excessive to the point evidence of wetting of lead and pad are not visible.

## INSUFFICIENT/MINIMUM SOLDER FILLET

*General*

Insufficient solder is identified by the lack of sufficient solder to form a fillet around the lead. If the lead and pad do not show good wetting the solder joint will probably not meet *acceptable* quality criteria.

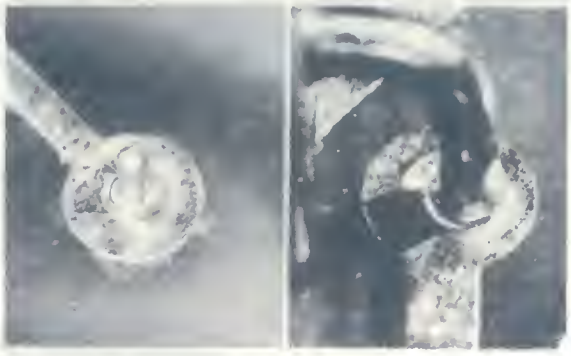
The acceptable (minimum) solder fillet will display the following:

(a) Good wetting of lead and pad.

(b) The cavity around the lead shall not exceed 25% of the hole depth (total percentage to be combination of the top and/or bottom side of the board).

(c) No cracks around the circumference of the pad at intersection of pad and hole wall.

ACCEPTABLE (Preferred)
Good solder fillet adhering to both lead and pad with complete coverage.



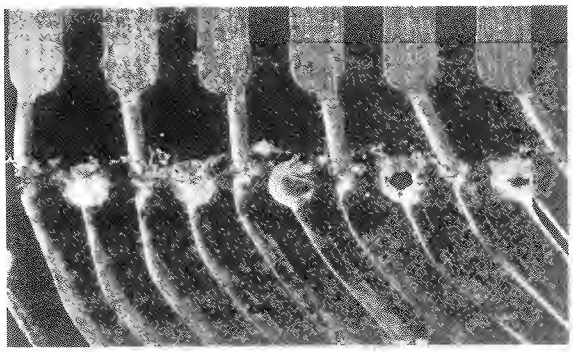
ACCEPTABLE (Minimum)
No solder fillet is visible, but solder displays good wetting around the lead and pad. Solder cavity is a maximum of 25% of the total hole thickness.

UNACCEPTABLE
Leads and pads show little or no wetting. Solder cavity is greater than 25% of the total hole thickness.

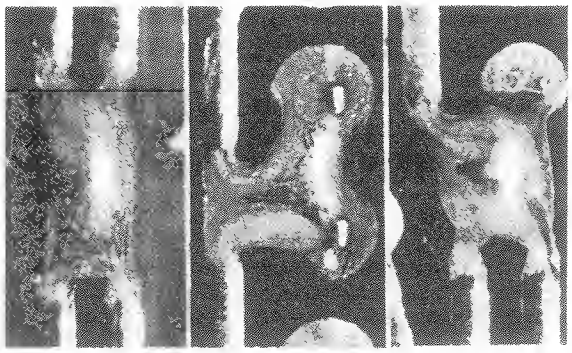
SOLDER BRIDGES

*General*

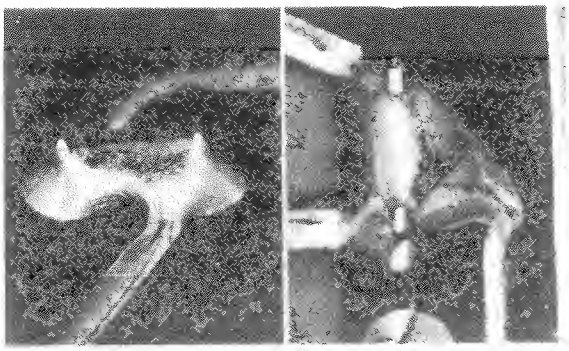
A solder bridge is a continuous conductive path (generally by excess solder) between two adjacent conductive surfaces.



UNACCEPTABLE
(Solder Bridges)
Solder splatter bridging trace and pads.



UNACCEPTABLE
(Solder Bridges)
Excess solder bridging traces.



UNACCEPTABLE
(Solder Bridges)
Excess solder bridging pads and traces.

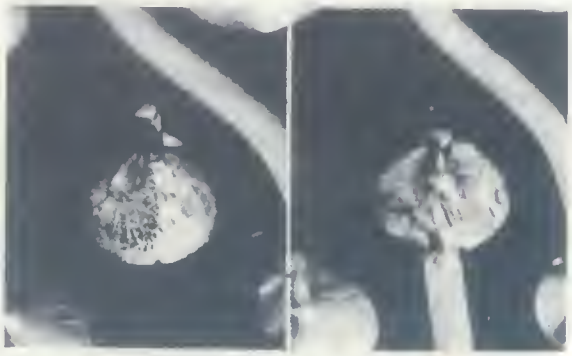
## FRACTURED/DISTURBED SOLDER JOINT

*General*

Disturbed joints are characterized by strain marks on the surface or by a rough gritty appearance.

Fractured joints are characterized by separation of the component lead from the solder fillet.

UNACCEPTABLE
(Disturbed Joints)
Rough gritty appearance.



UNACCEPTABLE
(Disturbed Joints)
Strain marks and dull color are typical of disturbed joints.

UNACCEPTABLE
(Fractured Joint)
Solder fillet has separated from the component lead. Possible cause, lead clipping.

## SOLDER PROJECTIONS

*General*

Solder projections that exceed the height requirement, reduce the conductor spacing in half, or to within 0.015 of a conductor, whichever is less, are not acceptable.

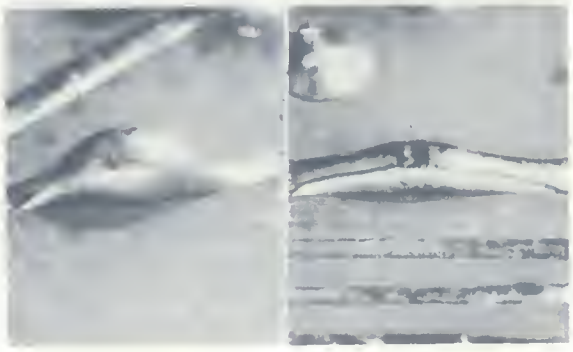
*High Voltage (50 volts and above)*

Solder projections that reduce the conductor spacing are not acceptable on high voltage boards.

*Peaks/Icicles*

This condition is basically an excessive solder formation, which because of its freezing shape, is conical, ending in a sharp point. Sharp points are not acceptable on high voltage boards.

ACCEPTABLE (Preferred)
No solder projections.



ACCEPTABLE (Minimum)
Solder projections that pass the solder projection requirement.

UNACCEPTABLE
Solder projections that exceed the solder projection requirement.

*NOTE:* Use Module Gages #9405111 and #9405078 to determine acceptability of solder projections.

## GENERAL UNACCEPTABLE CONDITIONS

*Solder Balls*

Solder balls on printed circuit assemblies are not acceptable.

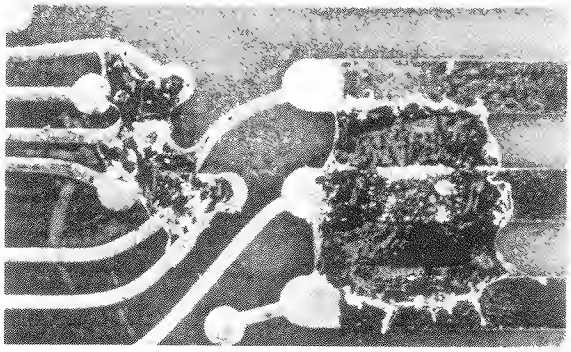
*Solder Splashes*

Solder splashes on printed circuit assemblies are not acceptable.

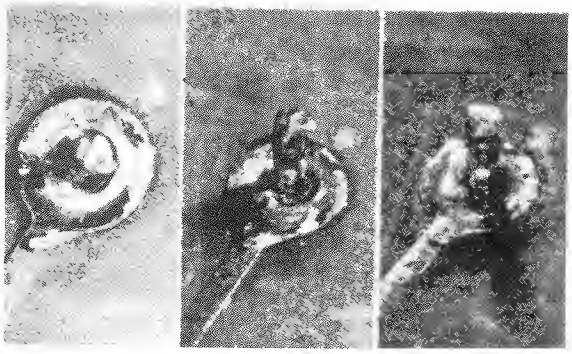
*Rosin Bonds*

Bond is achieved through a layer of solidified flux. In its worst form this joint has no metallic or electrical continuity and has little physical strength. Rosin bonds are not acceptable.

UNACCEPTABLE
(Solder Balls)
Solder balls on surface of printed circuit board.



UNACCEPTABLE
(Solder Splash)
Solder splash on printed circuit board surface.



UNACCEPTABLE
(Rosin Bond)
Joint bonded with rosin.

## DEWETTING

*General*

Dewetting is characterized by solder not completely covering the surfaces to be bonded. Solder appears as droplets or balls having withdrawn from previously wet adjacent areas or never wetting them at all. The maximum dewetting acceptable is 15% of the area of the joint to be bonded.

ACCEPTABLE (Preferred)
Good wetting on both lead and pad.

ACCEPTABLE (Minimum)
Not more than 15% of the lead or pad has dewetted.

UNACCEPTABLE
Fifteen percent or more of the lead or pad has dewetted.

COMPONENT SOLDERING

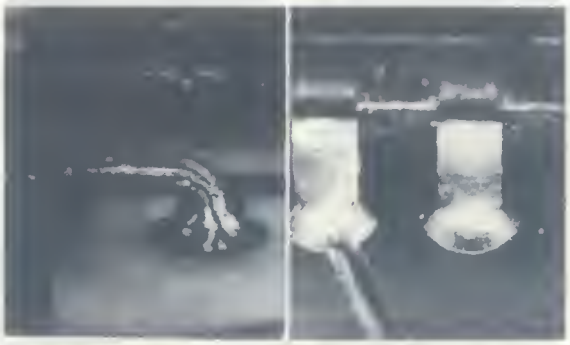
*Preferred*

Plated through hole containing component lead with conductor or pad connected to component and non-component side with conductor or pad shall exhibit the following:

(a) Complete wetting of pads and lead.

(b) Full fillet is evident both sides of printed circuit assembly.

ACCEPTABLE (Preferred)
(Component Side)
Good wetting of all surfaces. Displays a good fillet.



ACCEPTABLE (Preferred)
(Component Side)
Good wetting of all surfaces. Displays a good fillet.

ACCEPTABLE (Preferred)
(Non-Component Side)
Good wetting of all surfaces. Surfaces bright and shiny leads. A good fillet. Leads length meets the maximum projection requirement.

*NOTE:* Use Module Gages #9405111 and #9405078 to determine acceptability of component lead length.

## PADS – UNCLINCHED LEADS (PLATED THROUGH HOLE (PTH) BOARDS ONLY)

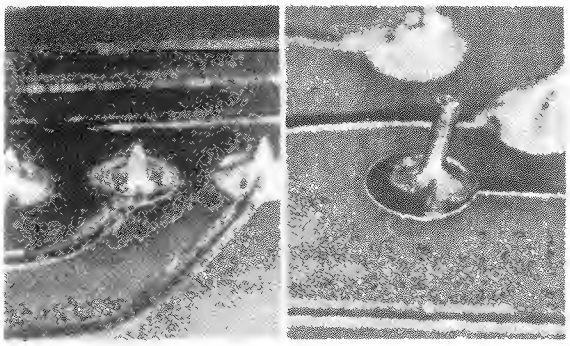
*General*

All component leads inserted into printed circuit boards and not clinched shall exhibit the following:

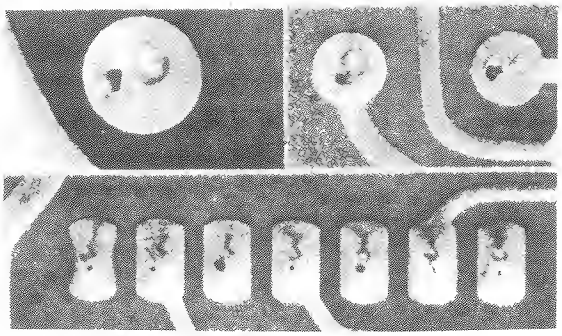
(a) Pads only (no conductor attached) can display pin holes and blow holes but shall display some evidence of wetting of lead to pad.

(b) Pads (with conductor attached) shall display good solder flow and wetting of component lead to pad with a maximum of one (1) pin hole or one (1) blow hole per solder connection.

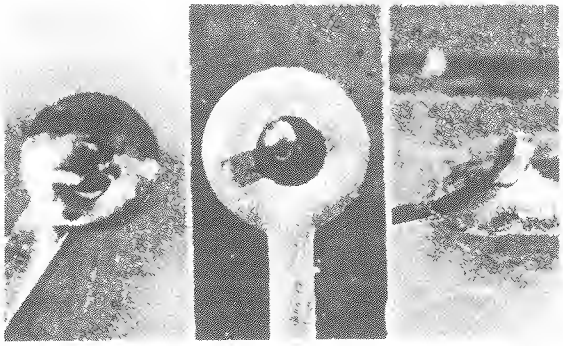
(c) A blow hole is acceptable if its size is less than the lead diameter and the lead is wetted around a minimum of 75% of its circumference.



ACCEPTABLE (Preferred)
Minimum solder. Complete fillet. Good wetting. No evidence of pin holes or blow holes.



ACCEPTABLE (Minimum)
Blow holes not exceeding diameter of component lead. Pin holes not exceeding maximum of two (2) per solder connection.



UNACCEPTABLE
Blow hole exceeds lead diameter. No solder flow or wetting of pad and component lead. Fractured solder connection.

## PADS (CLINCHED LEADS)

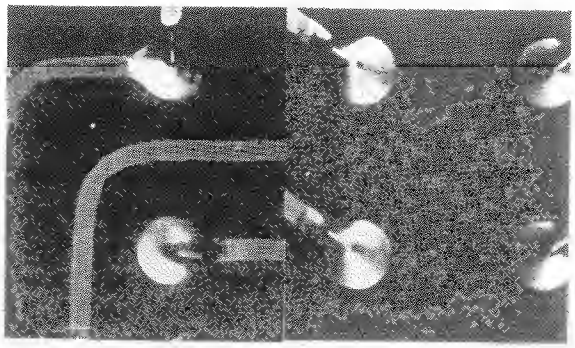
*General*

All component leads inserted into printed circuit boards and clinched shall exhibit the following:

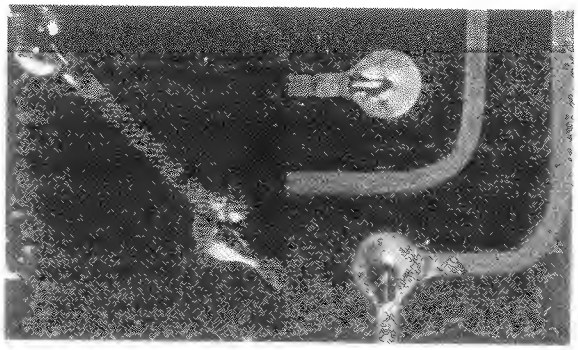
(a) Pads only (no conductor attached) can display pin holes and blow holes but shall display some evidence of wetting of lead to pad.

(b) Pads (with conductor attached) shall display good solder flow and wetting of component lead to pad with a maximum of one (1) pin hole or one (1) blow hole per solder connection.

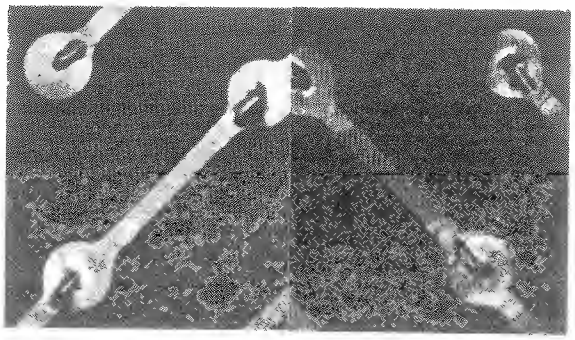
(c) Pin hole or blow hole of any size is acceptable in the access hole when there is *complete* wetting of the clinched lead to pad and conductor.



ACCEPTABLE (Preferred)
No pin or blow holes or other surface imperfections. Complete fillet around component lead and access hole. Complete solder fillet around lead, pad and conductor.



ACCEPTABLE (Minimum)
Pin and blow hole in access hole. Complete fillet of solder from component lead to pad and conductor which is also free from pin and blow holes and other imperfections.



UNACCEPTABLE
Incomplete fillet of solder from component lead to pad and conductor. Evidence of dewetting. Solder flow is broken between component lead and pad and conductor.

## INTERFACIAL HOLES (PLATED THROUGH HOLES (PTH)) WITH COMPONENTS)

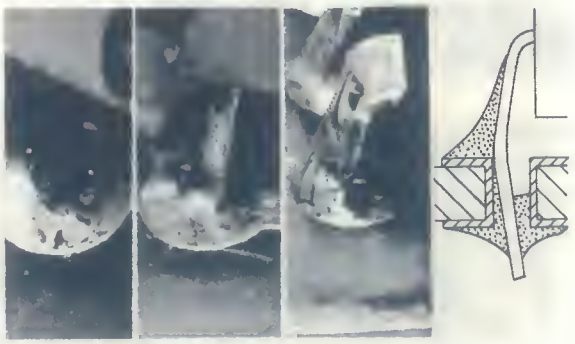
*General*

All component leads inserted into an interfacial hole (plated through hole (pth), eyelet, etc.) with attached conductor shall exhibit the following:

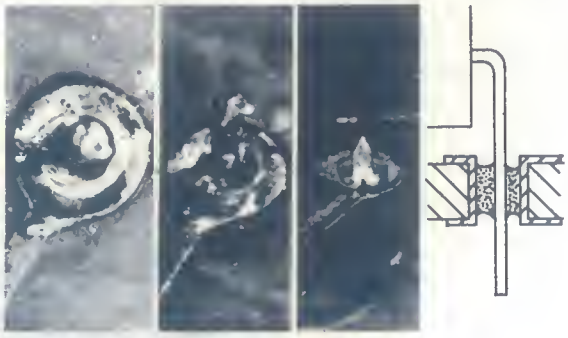
(a) Minimum solder fillet for component lead shall be 75% of lead circumference on side 2.

(b) Depression of solder fillet on side 2 around lead to a maximum of 25% of board thickness provided there is no evidence of non-wet, dewet, pin holes, blow holes or other solder connection imperfections.

ACCEPTABLE (Preferred)
Good solder fillet. Complete wetting of component lead and pad.



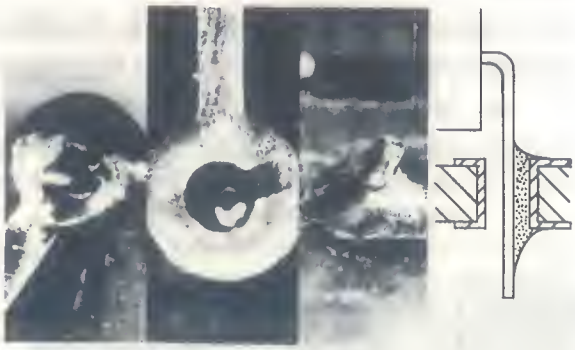
ACCEPTABLE
Pin holes, blow holes and voids on component side (side 1) of board.



ACCEPTABLE
Depression of solder on solder side (side 2) of board does not exceed 25% of board thickness.

INTERFACIAL HOLES (PLATED THROUGH HOLES (PTH)) WITH COMPONENTS (Cont.)

ACCEPTABLE (Minimum)
No lead wetting, fillet or solder on pad on component side (side 1) of board.



UNACCEPTABLE
Void in solder completely through the board. No solder flow or wetting of lead and pad. The solder joint is fractured.

*NOTE:* To determine acceptability of griplets refer to Engineering Specification A-SP-7665112-0-0.

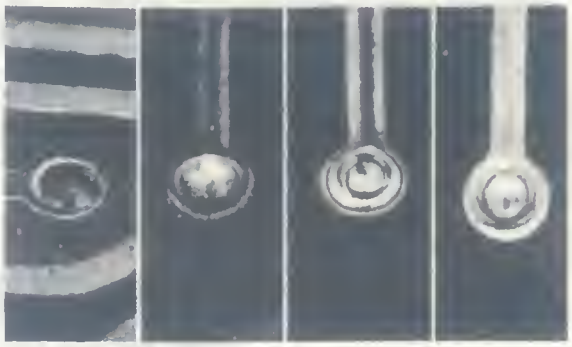
## INTERFACIAL HOLES (PLATED THROUGH HOLES (PTH)) WITHOUT COMPONENT LEADS

*General*

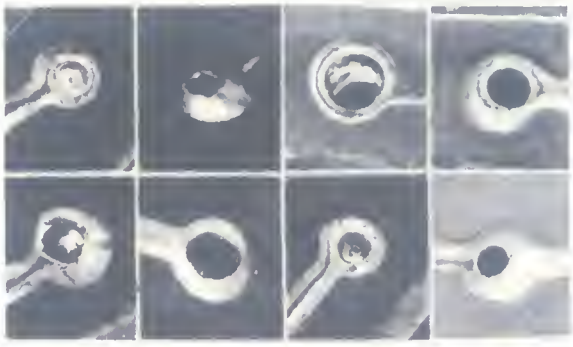
All unused holes on printed circuit boards with interfacial connections (pth) that do not have component leads or hookup wire (insulated and uninsulated types) inserted into them shall conform to the following:

(a) No cracks in the periphery of the plated through hole.
(b) No voids in the plated through hole wall.
(c) Does not have to have a solder plug.
(d) Can exhibit poor wetting (non-wet and de-wet).
(e) Can have large blow holes and pin holes.
(f) Can have excess solder.

ACCEPTABLE (Preferred)
Plated through hole contains a preferred solder plug.



ACCEPTABLE
1. Pad exhibits evidence of minimum solder flowing on top side.
2. Plug may be depressed any amount.
3. Good wetting of hole and wall.
4. Hole contains a solder plug.



ACCEPTABLE (Minimum)
No solder. Poor wetting. Insufficient solder. Blow holes. Large pin holes. Excess solder. No cracks around pth. No voids in pth.

(BLANK)

UNACCEPTABLE
Unacceptable conditions of the interfacial connection (pth) shall be verified under magnification.

INTERFACIAL HOLES (PLATED THROUGH HOLES (PTH)) WITHOUT COMPONENT LEADS (Cont.)

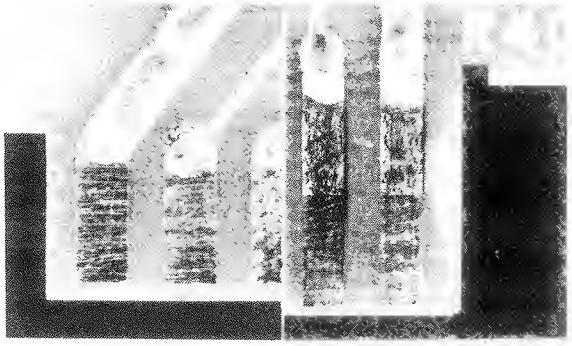
*NOTES:*

1. To determine acceptability of griplets refer to Engineering Specification A-SP-7665112-0-0.
2. Interfacial holes (feedthrough eyelets) must display a complete solder fillet to at least one (1) petal of the eyelet on each side of the board even though the eyelet may not be filled with solder.

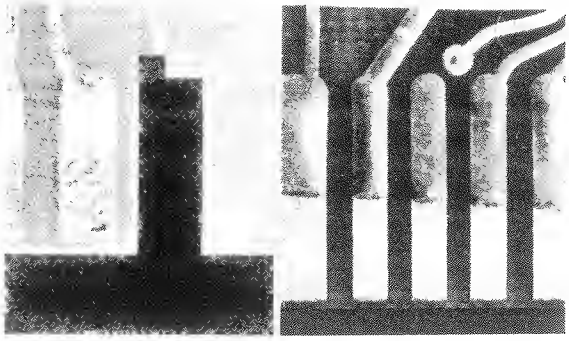
SOLDER ON CONTACT FINGERS

Excess solder or solder film on printed circuit contact fingers 1/8 inch (0.125) maximum, as measured from the notch, shall be considered acceptable.

ACCEPTABLE (Preferred)
No solder down on contact finger. Solder on contact finger less than 1/8 inch (0.125) from notch.



ACCEPTABLE (Minimum)
Solder is at the maximum of 1/8 inch (0.125) down on contact finger from notch.

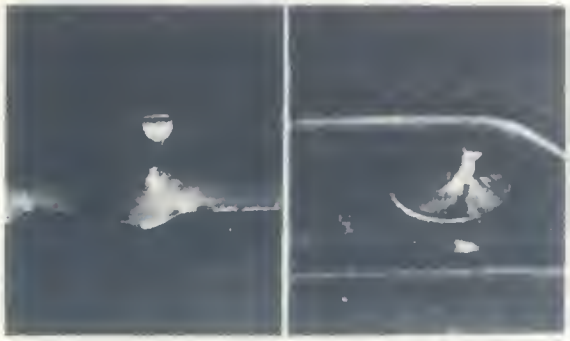


UNACCEPTABLE
Solder is down on contact finger more than 1/8 inch (0.125) from the notch.

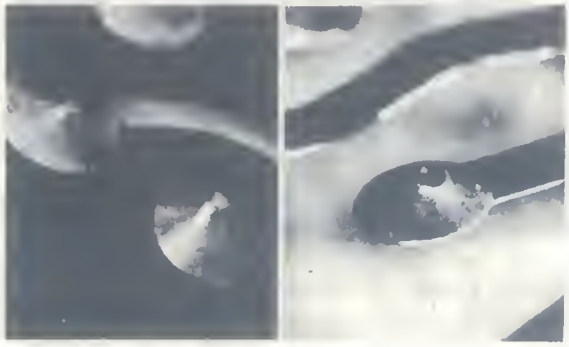
## COMPONENT LEAD PROTRUSION

*General*

Component leads must be long enough to extend through the printed circuit board. There must be evidence of the component lead on the non-component side of the printed circuit board. Visible evidence of wetting shall be seen. The protrusion of the component lead shall not exceed the maximum length requirement of 1/16 inch (0.063) on the solder side (side 2) of the board.



ACCEPTABLE (Preferred)
Lead protrudes through the solder to form a fillet.



ACCEPTABLE (Minimum)
Minimum fillet with lead outline visible.

UNACCEPTABLE
No evidence of fillet or lead outline visible.

*NOTE:* Use Module Gages #9405111 and #9405078 to determine acceptability of component lead length.

## PRINTED CIRCUIT BOARDS (MODULES) ASSEMBLY REPAIR, REWORK AND RETROFIT

*General*

*Repair and Rework*

Repairs and rework resulting from damage during the assembly and thereafter shall be permitted.

Printed circuit boards shall not be repaired when the repair will degrade or reduce the electrical properties of the intended use of the assembly.

*Workmanship*

The quality of workmanship relative to repair shall be the same as for original assembly. When repair is incorporated, special emphasis shall be made to assure uniformity and neatness.

*NOTE:* See page 4-64 for listing of Engineering Specifications that govern repair, rework and retrofit.

MODULE REPAIR/REWORK/RETROFIT PROCEDURES REFERENCED

| | |
|---|---|
| Rework Spec. | A-SP-7605845-0-0 |
| Touch-up Spec. | A-SP-7665010-0-0 |
| Single Side PC Board Inspection | A-SP-7665026-0-0 |
| Flip Chip Final Inspection | A-SP-7665039-0-0 |
| Memory Stack Inspection | A-SP-7665085-0-0 |
| Soldering Standard | A-SP-7665105-0-0 |
| Multilayer Rework Spec. | A-SP-7665169-0-0 |
| Module Repair Spec. | A-SP-7665177-0-0 |

*NOTE:* Additional references can be obtained from Engineering Specification A-SP-7665000-0-0 (Format and Index Specification)

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SECTION 5.0 – SAFETY/WORK PRACTICES

## PURPOSE

The purpose of this section (5.0) is to preclude the possibility of personal injury and damage to products due to unsafe acts or unsafe conditions. Provided are guidelines relative to safety and work practices that everyone should be aware of at all times during the performance of daily work routines.

## SAFETY

The safety of a work area depends on the continual development of safety practices by all personnel. A list of safety practices appears below:

*ALWAYS*

(a) Be careful! Accidents are usually caused by unsafe acts and/or unsafe conditions.

(b) Report all injuries to your supervisor immediately; if necessary obtain medical attention.

(c) Point the open side of diagonal cutters away from your face. Eye protection should be worn! Make certain the metal clippings are not aimed at anyone in the vicinity or into assemblies.

(d) Remove solder joints carefully. A wire under tension may spring up and flip molten solder toward your face or someone near by. Eye protection should be worn.

(e) Unplug your soldering iron when leaving it unattended for a length of time. Hot irons left unattended have caused fires.

(f) Place your soldering iron in a holder and in a position such that you never have to reach across it – this minimizes the possibility of burns.

(g) Be careful when using cleaning solvents. Avoid splashing them into your face or someone near by. Eye protection should be worn.

(h) Plug soldering irons into known, proper voltage convenience outlets and keep plug free from strands of wire or metal – this reduces the possibility of electrical short circuit or electrical shock.

(i) Make certain solvents are properly identified and stored in approved containers especially when flammable.

(j) Use air hoses provided with a nozzle that reduces the air line pressure to 30 PSI – never horseplay with air hoses.

(k) Obtain replacements for broken or worn tools as they could cause personal injury.

*NEVER*

(a) Eat or smoke in an area where toxic chemicals are used. (examples are lead (solder) and trichlorethylene)

(b) Overload a skid – it will tip over and cause personal injury.

(c) Work on equipment unless the power is off. The safest way to be sure is removal of the plug from the convenience outlet – this eliminates the electrical shock hazard.

(d) Work on equipment containing high voltage power supplies or display tubes (CRT's) without discharging the residual (stored) voltages – if you are not sure ask your supervisor! This will eliminate potential electrical shock and/or personal injury.

(e) Drape power cords or air hoses across aisles or doorways – this eliminates tripping and falling hazards.

(f) Ride on lift truck not designed for a driver and never ride on moving skids.

(g) Leave metal clippings, filings or other metal in electronic assemblies – this eliminates potential electrical short circuits and personal injury.

(h) Leave packaging material laying around as it creates a fire hazard and displays poor housekeeping.

*NOTE:* Where questions regarding safety arise contact your local safety coordinator or the safety department.

## WORK PRACTICES

There are certain accepted rules regarding all assembly and fabrication jobs. Most of these "good practices" are just extentions of good common sense and safety. There is one good practice which applies to any situation:

> IF YOU DON'T UNDERSTAND WHAT YOU ARE DOING, *STOP* AND ASK YOUR SUPERVISOR.

*ALWAYS*

(a) Keep your work station clean and orderly – "there is a place for everything and everything should be in its place".

(b) Take pride in your work, check it over for conformance to the requirements before you pass it on.

(c) Pick up parts which have fallen on the floor, the smallest part is most often the most expensive.

(d) Clean the equipment you are working on; remove all flux and other contaminants with approved cleaning solvents.

(e) Keep unneeded tools, pocketbooks, clothing, etc., off the top of work benches or out of work areas – it creates fire hazards and reflects poor housekeeping habits.

(f) Clean up your work station of all dirt and waste materials which accumulate as a direct result of the performance of your job.

*NEVER*

(a) Slide a finished assembly across the work bench or other surfaces as this results in very deep scratches.

(b) Stack painted or chromic-coated parts on one another or bring them into contact with sharp edges, screws, nails, etc. as this also will result in very deep scratches to the finished surfaces.

(c) Write defects on an assembly or part directly or on masking tape – always use appropriate tags or stickers and give clear, concise reason for defect.

(d) Place any finished parts/assemblies directly on the floor – it will get dirty or damaged.

(e) Overload a skid with material – it will either crush the material below it (overload) or tip over and damage will result.

(f) Use masking tape or other unapproved sticky tags/papers on finished surfaces of parts/assemblies – a residue is left on the surface that is almost impossible to remove causing damage to the surface.

## CARE OF TOOLS

Experience has shown that there is a direct association between the way a person keeps his tools and the quality of work he produces. Following are some guidelines on the care of tools:

*ALWAYS*

(a) Keep your tools clean and in good working order.

(b) Select the correct tool for the job.

(c) Guard and protect your tools from loss, etc.

(d) Place your tools into your tool box when not in use.

*NEVER*

(a) Use pliers to loosen or tighten nuts and bolts.

(b) Use a screwdriver as a chisel or lever.

(c) Use diagonal cutters to cut large cross section metal items such as nails, etc.

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SECTION 6.0 – WIRE PLACEMENT

## PURPOSE

The purpose of this section (6.0) is to establish and provide photographic representation of the ACCEPTABLE (PREFERRED), ACCEPTABLE (MINIMUM) and UNACCEPTABLE quality levels as they apply to WIRE PLACEMENT. These requirements shall prevail when specific information does not appear on Engineering documentation. Engineering documentation may define specific quality requirements which take precedence over general workmanship standards.

## WORKMANSHIP

All details of workmanship shall be in accordance with high-grade industrial electrical wiring and equipment installation practices as reflected in the following standards.

## DEFINITIONS

*General Definition*

Wire placement is the term applied to the final wiring configuration of an assembly. It includes the location and routing of wires, their mechanical support, method of making connections to component terminals, and general workmanship and neatness. Wire and cables must meet the requirements of this section after being subjected to normal handling and installation.

*Dressing*

The manner in which lead wires are installed, routed and terminated to produce a neat, reliable unit.

*Grommet*

A rubber protector used to cover sharp edges of a hole through which conductors are run.

*Point-to-Point*

When pertaining to wire, is that wire which takes the most direct route between terminals, provides some service loop, and is not taut.

*Wire Routing*

The placing, clamping and connecting of a group of wires so that the chance of damage due to heat or stress will be reduced to a minimum.

## ROUTING

*Sharp Corners*

Wires and cables shall be routed in such a manner that they are not curved or bent around sharp corners, screwthreads or under screws, nuts, washers, etc. Where this cannot be avoided, appropriate insulation, etc., shall be used. Electrical tape shall not be used for protection from sharp corners or edges. All wiring routed through holes in panels less than 1/8 (0.125) inch thick must have a grommet installed to prevent chafing. Panels more than 1/8 (0.125) inch thick shall have a 1/16 (0.063) inch minimum radius or grommet.

ACCEPTABLE (Preferred)
Wires are protected from sharp sheet metal edge by suitable insulation. Preferred routing is to route wires away from sharp edges.

(BLANK)

ACCEPTABLE (Minimum)
There are no minimum acceptable conditions that apply.

UNACCEPTABLE
Wires not protected from sharp sheet metal edge.

*Moving Parts*

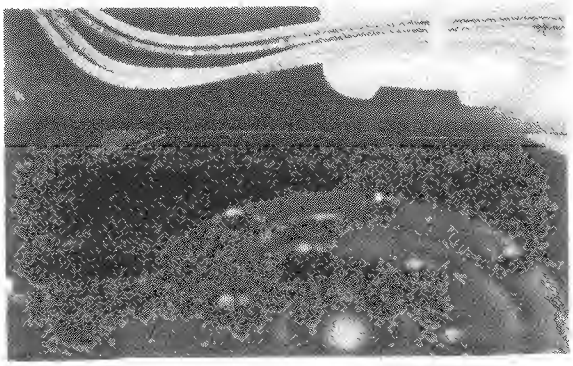
There shall be no interference by wires or cables with normal movement of parts in operation and servicing of the equipment. Wires and cables shall be spaced approximately 1/8 (0.125) inch away from smooth operating movable parts such as rotating shafts, wheels, etc. Wires and cables shall be spaced approximately 1/2 (0.500) inch away from rough operating movable parts such as gears, fan blades, link-belts, etc., unless a suitable guard is installed.

*Component Leads*

Component leads shall not be used as jumpers between terminals.

*General Routing*

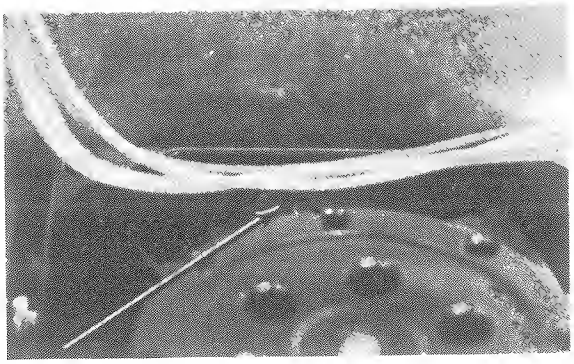
Routing must be open and orderly to permit inspection, maintenance and repair. All routing shall be neat in appearance. Adjustable components (potentiometers, etc.) and adjustment holes, etc., must be accessible. Whenever possible, component covers and mounting screws should be accessible for repair or replacement.



ACCEPTABLE (Preferred)
Cable is mounted approximately 1/2 inch away from rough moving parts (fan blade).

(BLANK)

ACCEPTABLE (Minimum)
There are no minimum acceptable conditions that apply.



UNACCEPTABLE
Cable is mounted too close (much less than 1/2 inch) to fan blade.

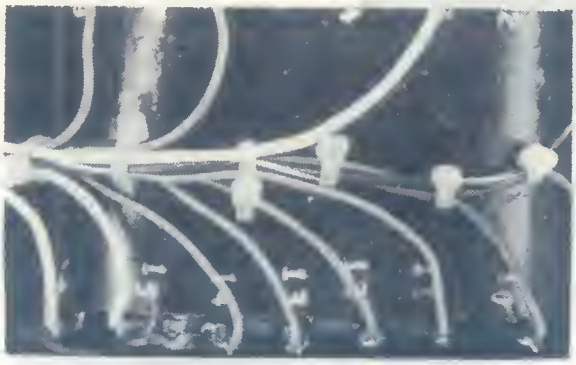
## SERVICE LOOP

*General*

Sufficient slack (service loop) shall be provided to prevent any stress on the connections and to facilitate removal. Service loops on a harness or cable shall be uniformly dressed to prevent stress concentration on any one wire. The loop shall be long enough to allow field repairs to the connection. It shall also allow parts to be removed and replaced during servicing without removing other parts.

ACCEPTABLE (Preferred)
Service loops are uniform and of sufficient diameter and length to prevent stress on the connection and permit field repairs.

ACCEPTABLE (Minimum)
Service loops are not uniform but are sufficient for field repairs.



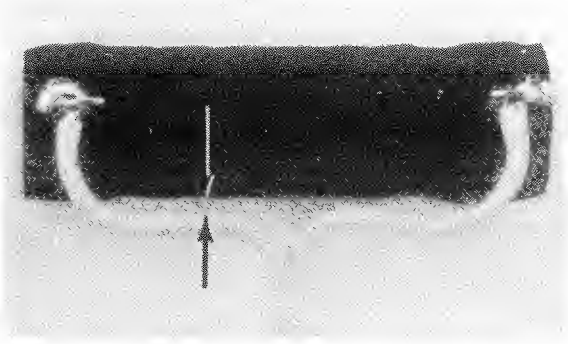
UNACCEPTABLE
Service loops are not long enough to permit field repairs or prevent the wire from stressing the connection

## HEAT GENERATING COMPONENTS

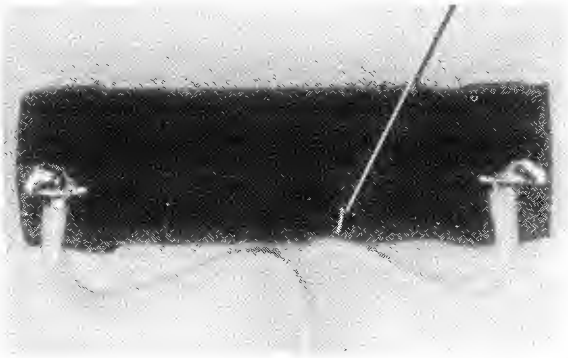
*General*

Clearance between wires or cables and parts which radiate heat such as power semiconductors, power resistors, lamps, semiconductors, heat sinks, etc., shall be sufficient to avoid deterioration of the insulation as a result of heat dissipation. Wires shall not be routed closer than 1/8 (0.125) inch to heat generating components.

ACCEPTABLE (Preferred)
Wires are routed away from heat generating component.



ACCEPTABLE (Minimum)
Minimum acceptable routing of wires near heat generating components shall be a minimum of 1/8 (0.125) inch from component.



UNACCEPTABLE
Unacceptable routing, wire laying on heat generating component.

## SUPPORT AND SECUREMENT

*General*

Wires and cables shall be properly supported and secured to prevent undue stress on conductors and terminals and to prevent any permanent change in their relative position.

*Sharp Edges*

Unless grommets or other appropriate protective insulation are used, wires and cables shall be secured to prevent them from coming in contact with sharp edges, corners or screw threads.

ACCEPTABLE (Preferred)
Grommet protects wires from sharp metal edges.

(BLANK)

ACCEPTABLE (Minimum)
There are no minimum acceptable conditions that apply.

UNACCEPTABLE
Wire is in contact with sharp edge permitting chafing and/or cutting of wire insulation. There is no minimum acceptable for sharp edges.

## STRAIN RELIEF

*General*

Wires and cables shall be properly supported with tie downs to prevent mechanical strain or tension on any wire or component lead. Wire bundles shall not be supported by terminals or component leads.

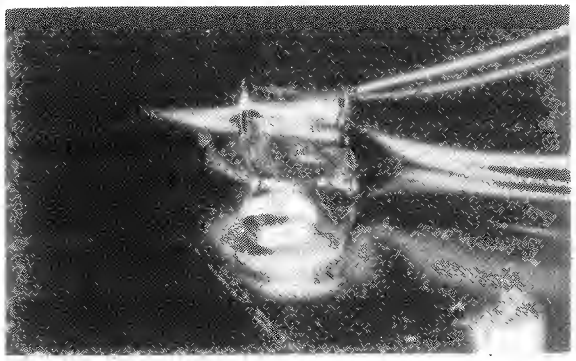
*Cable Clamps*

Unless otherwise specified, wire bundles shall be tied down at the intervals shown in the table below. The cable clamps must restrain the cable from movement in any direction. All cable clamps should be securely fastened to an item such as a chassis, post, bracket, etc. The cable clamp must not pinch, cut or abrade the wire or cable. Cable clamps shall not be secured to heat producing components such as semiconductor heat sinks, motors, etc., unless the wire insulation is rated for the temperature encountered and there is no other means available.

TABLE 6.1

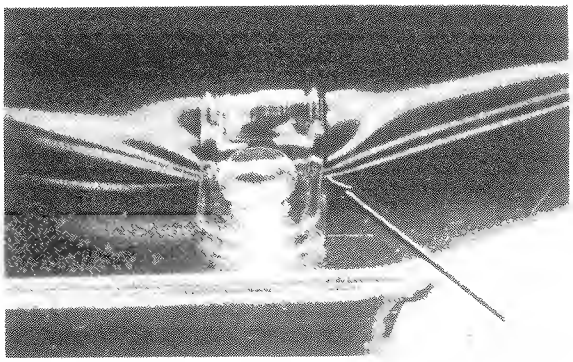
| CABLE/BUNDLE DIAMETER | MAXIMUM TIE DOWN INTERVAL |
|---|---|
| 1/4" and smaller | 8 inches |
| 1/4" to 1/2" | 10 inches |
| 1/2" to 3/4" | 15 inches |
| 3/4" and larger | 20 inches |

Additional insulation must be provided between metal clamps and wires, or cables. The configuration of the cable must not cause insulation damage.



ACCEPTABLE (Preferred)
Cable clamp restrains cable from movement in any direction.

(BLANK)



ACCEPTABLE (Minimum)
The minimum acceptable conditions that apply are found in Table 6-1.

UNACCEPTABLE
Unacceptable cable clamp; pinches bundle of wires.

## WIRE TERMINATION

*Installation of Terminals on Screw Thread Assemblies*

Terminal lugs shall be used to terminate conductors to screw thread assemblies. The installation of two or more terminal lugs on a screw thread assembly shall be such as to provide parallel contact surfaces on the tongues of adjacent terminals. Whenever possible, the installation shall be accomplished without any bending of the terminal lugs. Where it is impossible to install terminal lugs without bending, the terminal lugs may be bent, but only to the extent necessary to provide the parallel surface required. In no case shall a terminal be bent so as to exceed an angle of 45 degrees.

*Ring Tongue Terminal Lug*

Not more than four (4) ring tongue terminal lugs or three (3) ring tongue terminal lugs and a tie bus bar shall be installed on any one screw or post.

*Spade or Fork Tongue Terminal Lug*

Spade and/or fork tongue terminals shall have the capability of being retained under the head of the screw by means of a locking or up-turned fork. A maximum of two spade or two fork tongue terminal lugs shall be installed on any one terminal screw or post.

ACCEPTABLE (Preferred)
A maximum of three (3) ring tongue and a tie bus bar.

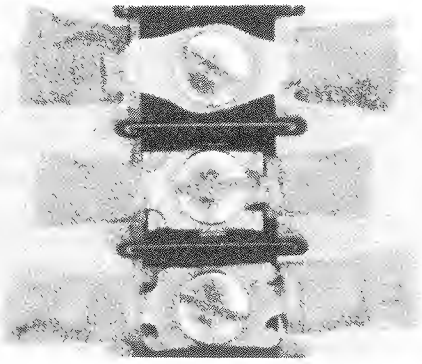
ACCEPTABLE (Minimum)
A maximum of four (4) ring tongue on any one screw.

UNACCEPTABLE
Exceeding three (3) ring tongue terminals and a tie bus bar.

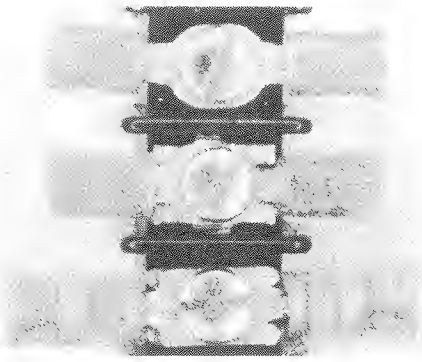
## BARRIER TERMINAL STRIP (SINGLE ROW)

*General*

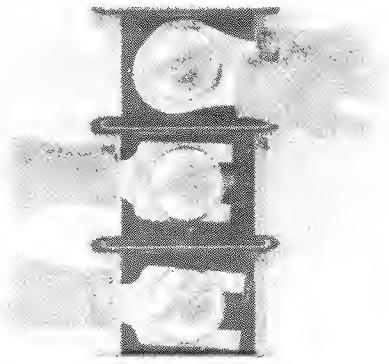
Single Row of Screws: Barrier strips with a single row of screws may have four (4) ring tongue (two on each side) or two (2) spade or fork tongue terminal lugs on any one screw (one on each side).



ACCEPTABLE (Preferred)
Preferred terminals on a single screw barrier strip shall be two ring tongue, two spade or two ring tongue terminals on any one screw.



ACCEPTABLE (Minimum)
Minimum acceptable terminals on a single screw barrier strip shall have a maximum of four ring tongue, two spade or two fork tongue terminals on any one screw.

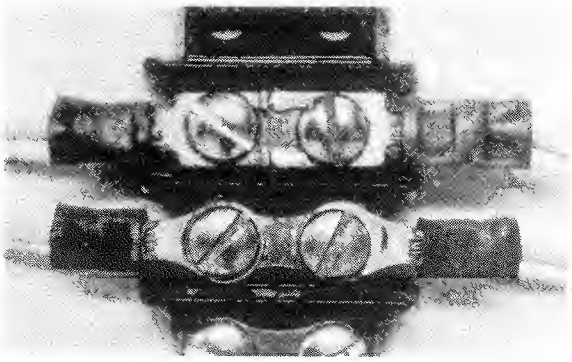


UNACCEPTABLE
Unacceptable terminals on barrier terminal strip, spade terminal installed up-side-down, three terminals stacked on same side of screw.

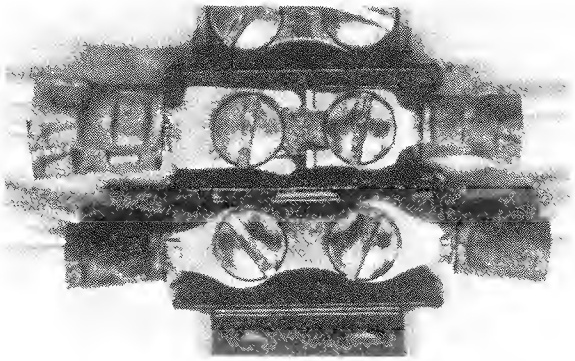
BARRIER TERMINAL STRIP (DOUBLE ROW)

*General*

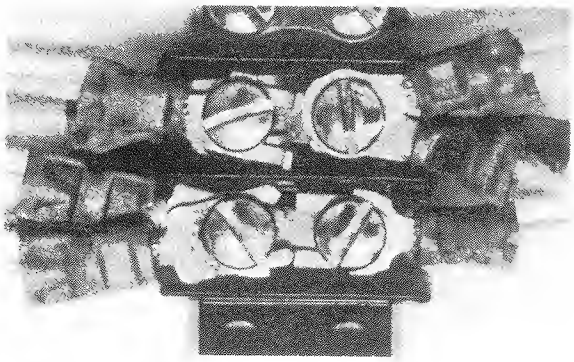
Double Row of Screws: Barrier strips with two (2) rows of screws shall have a maximum of two (2) rings or locking fork tongue or one (1) spade terminal lug on any one screw.



ACCEPTABLE (Preferred)
Preferred terminals on a barrier terminal strip shall be one terminal per screw.



ACCEPTABLE (Minimum)
Minimum acceptable stacking of terminals on two screw barrier terminal strip shall be two (2) ring or locking fork tongue or one (1) spade terminal on any one screw.



UNACCEPTABLE
Unacceptable stacking of ring tongue and spade terminals.

## FLASHOVER CLEARANCE

*General*

Uninsulated portions of conductors, terminals, wire ends, etc., must be spaced approximately 1/32 (0.031) inch apart to avoid potential shorting or flashover. Where the possibility of subsequent movement exists which would reduce the spacing to less than 1/32 (0.031) inch, the leads shall have sleeving securely applied. Sleeving shall not be applied over sharp projections.

## TERMINAL AND CONDUCTOR MODIFICATIONS

*General*

Terminals which have been modified to accept smaller or larger size conductors and/or screws are not acceptable. Solder tabs on terminal strips shall not be used for quick-disconnect terminals unless they are specifically designed by the manufacturer for this purpose or as specified in Engineering Documents.

> *NOTE:* If wire placement involves soldering, the critereon established in Section 7.0 WIRE TERMINATIONS shall apply.

RETROFIT/REWORK/REPAIR PROCEDURES REFERENCES

*NOTE:* Refer to Engineering Specification A-SP-7665000-0-0 (Format and Index Spec.) for specific information.

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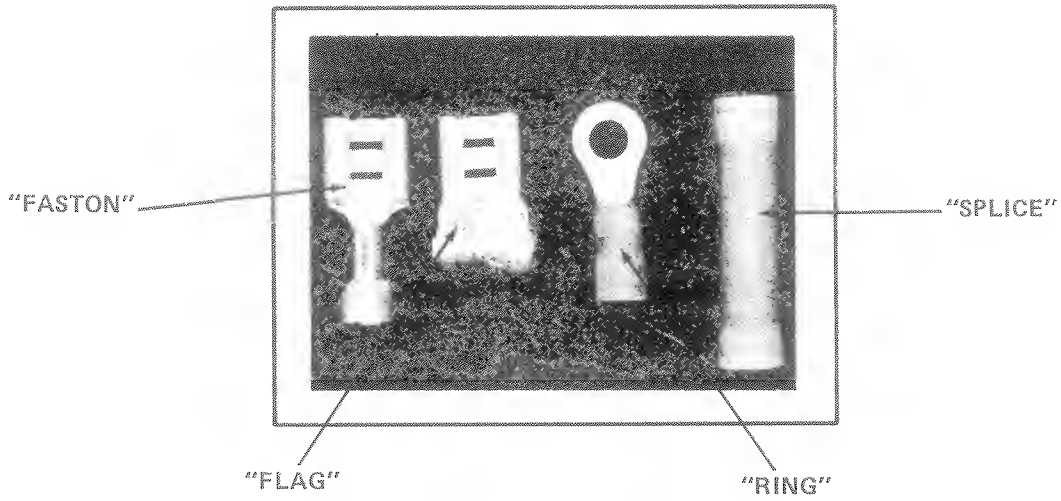
7.0 – WIRE TERMINATIONS

## PURPOSE

The purpose of this section (7.0) is to establish and provide photographic representation of the ACCEPTABLE (PREFERRED), ACCEPTABLE (MINIMUM) and UNACCEPTABLE quality levels as they apply to WIRE TERMINATIONS. These requirements shall prevail when specified information does not appear on Engineering documentation. Engineering documentation may define specific quality requirements which take precedence over general workmanship standards.

## WORKMANSHIP

All details of workmanship shall be in accordance with high-grade industrial electrical wiring and equipment installation practices as reflected in the following standards.




Most common types of wire terminators

Figure 1

## DEFINITIONS

*Bird-Caging*

Stranded wires separated generally in area between insulation and terminal points.

*Braid*

A machine woven textile yarn of fine metallic wire covering applied over the wire.

*Bifurcated Terminal*

A bifurcated terminal (split lug) is a terminal containing a slot in which wires and leads are placed before soldering.

*Continuity Test*

An electrical test to confirm presence of a complete electrical connection.

*Crimping*

A method of attaching a solderless terminal (or lug) to a wire. A proper crimping tool must be used to squeeze (crimp) the terminal upon the wire.

*Eyelet Terminal*

An eyelet (pierced) terminal is a terminal containing an eyelet or hole, through which leads (wires) are placed before soldering.

*Ground Lug*

A part used in connecting a wire to ground, and usually attached to the metal chassis or the component metal parts.

*Hollow, Cylindrical Terminal*

A hollow, cylindrical solder-cup (pot) is a terminal that is designed to accommodate not more than one lead (wire) inserted into the opening until lead (wire) "bottoms" in the receptacle.

*Hook Terminal*

A terminal formed in a hook shape; it is generally found on sealed relays.

*Insulation Damage, Thermal*

Excessive heat application resulting in insulation melting (burned, wrinkled appearance).

*Insulated*

Insulated means separated from other conducting surfaces by a dielectric, offering a high resistance to the passage of current.

> *NOTE:* When any object is said to be insulated, it is understood to be insulated in a suitable manner for the conditions to which is is subjected.

*Lead*

A length of stranded insulated wire used to interconnect terminal points.

*Lug*

A metal device of various sizes, either soldered or crimped onto the end of a conductor. The lug is a mechanical means of making an electrical connection at a terminal or terminal strip.

*Mechanical Wrap*

Prior to soldering, the wire or lead is secured snugly around the terminal.

*Oxide*

A nonmetallic film present on all common metals. Oxygen from the air unites with the surface of the terminal and wire to form a ceramic or oxide cover that tends to separate and insulate the terminal and wire, in spite of an acceptable mechanical wrap. Rosin, and only rosin, removes this oxide film.

*Stand-Off*

A single terminal insulated from and usually mounted on the chassis for the purpose of bringing together to a common point two or more wires of similar electrical characteristics.

*Split Lug*

See bifurcated terminal.

*Terminals*

A terminal is a tie-point device used for convenience in making electrical connections. There are five basic styles of terminals: (1) turret, (2) bifurcated, (3) eyelet, (4) hollow cylindrical, and (5) hook type.

*Turret Terminal*

A turret terminal is a round, post-type, grooved stud around which wires and leads are snugly hooked. It may have either spacing shoulders or grooves for positioning the leads.

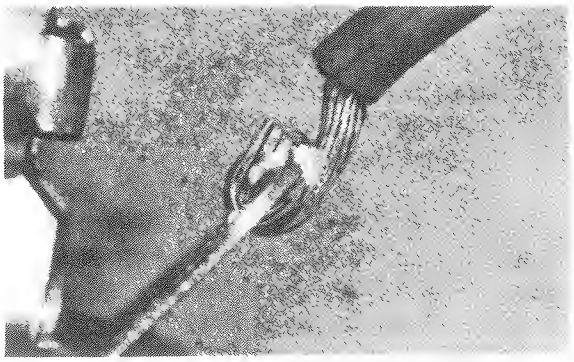
DAMAGED INSULATION

*Hook-up Wire*

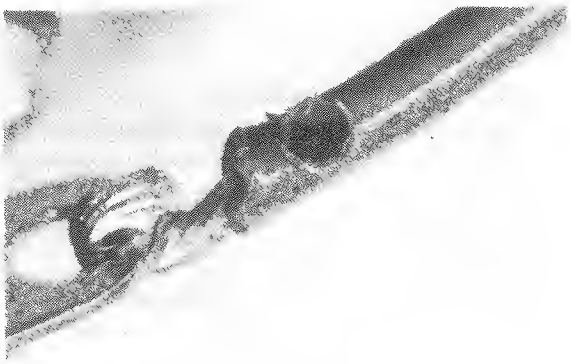
Cuts, burns, nicks or other insulation damage that extends less than one half the thickness of the insulation is acceptable.

*General Wire*

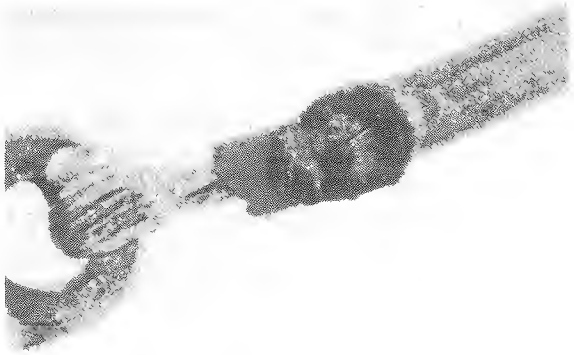
Cuts, burns, or other insulation damage that reduces the insulation wall thickness to less than one half its thickness is unacceptable.



ACCEPTABLE (Preferred)
No insulation damage.



ACCEPTABLE (Minimum)
Cuts, burns, nicks extend less than one half the thickness of the insulation.



UNACCEPTABLE
Cuts, burns, nicks, etc., are more than one half the thickness of the insulation.

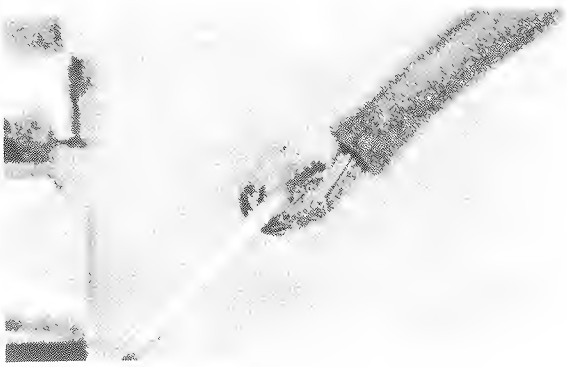
SECURING LEAD

*General*

No wire connection to a terminal shall depend solely upon solder for its mechanical strength. The conductor must be held sufficiently tight that it will not move during the soldering operation.

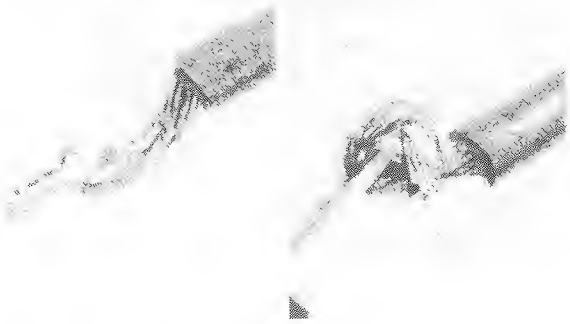
*Mechanical Wrap*

Before soldering, all wires or leads shall be fastened to terminals with a wrap a minimum of one half (1/2) to a maximum of one (1) full turn for mechanical security.



ACCEPTABLE (Preferred)
Wrap is 3/4 of a turn around the terminal.

ACCEPTABLE (Minimum)
Wrap is a minimum of 1/2 of a turn around the terminal. Wrap is a maximum of 1 full turn around the terminal.



UNACCEPTABLE
Wrap is less than 1/2 turn around the terminal; wrap is greater than 1 full turn around the terminal.

## TENSION

*General*

The wire shall be wrapped in a manner such that any tension will be transmitted to the terminal and not to the solder.

ACCEPTABLE (Preferred)
Lead routed in a semi-circle in the same direction as the wrap.

ACCEPTABLE (Minimum)
Lead routed straight out from the terminal.

UNACCEPTABLE
Lead routed in opposite direction of wrap.
Tension is on solder and not on terminal.

## STRIP GAP

*General*

Strip gap shall be measured from the end of the insulation to the printed circuit board or terminal. In no case shall the strip gap permit the flashover distance to other conductors, terminals, or printed circuit board traces to be less than 1/32 (0.031) inch.

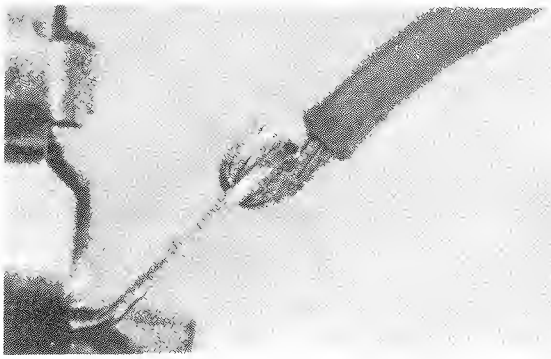
*Minimum Insulation Clearance*

The insulation may touch, but shall not be imbedded in the solder fillet.

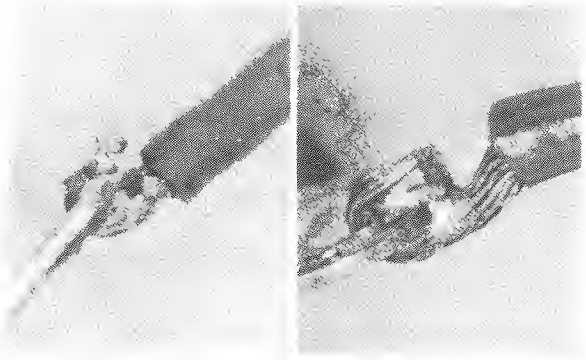
*Maximum Insulation Clearance*

The maximum insulation clearance shall be one (1) wire diameter (including insulation) or approximately 1/8 (0.125) inch. Whichever is greater.

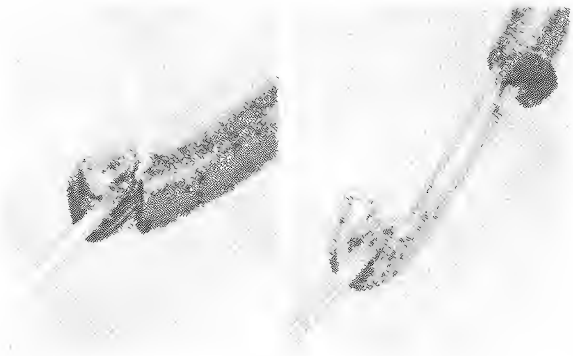
*NOTE:* Soldering into split lug on printed circuit boards, the insulation must be no more than 3/16 (0.188) inch from split lug.



ACCEPTABLE (Preferred)
Strip gap not exceeding approximately one (1) wire diameter.



ACCEPTABLE (Minimum)
Insulation not imbedded into solder joint. Insulation clearance is one (1) wire diameter maximum.



UNACCEPTABLE
Insulation imbedded into solder fillet. Contour of wire *not* visible. Strip gap much greater than one (1) wire diameter.

## MULTIPLE PARALLEL ENTRY

*General*

For multiple parallel entry of wires to a terminal, insulation clearance need not be equal. However, maximum and minimum strip gaps shall not be exceeded.

ACCEPTABLE (Preferred)
Multiple parallel wires with insulation equal.

ACCEPTABLE (Minimum)
Multiple parallel entry wires with minimum and maximum strip gap.

UNACCEPTABLE
Multiple parallel entry wire with strip gap exceeding maximum strip gap. Insulation in solder fillet. Melted insulation.

## WICKING

*General*

Wicking of solder is a condition in which solder has travelled along the strands, causing them to form essentially a single strand.

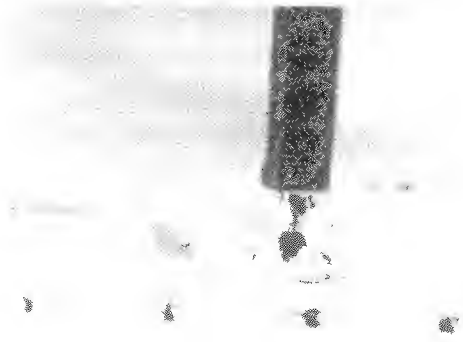
*Limitations*

Wicking is acceptable with the following limitations:

(a) Wicking does not exceed approximately two (2) wire diameters (including insulation) or 1/8 inch (0.125) (whichever is greater) under the insulation.

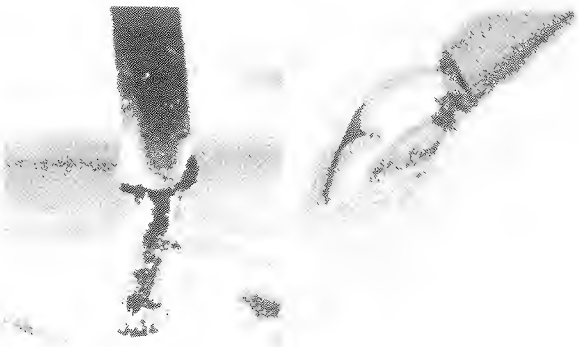
(b) Contour of wire visible at end of insulation.

(c) Insulation is not melted or damaged.



ACCEPTABLE (Preferred)
No wicking of solder under insulation.

ACCEPTABLE (Minimum)
Wicking not exceeding two (2) wire diameters or 1/8 inch (0.125) under the insulation contour of wire visible at end of insulation.



UNACCEPTABLE
Wicking greater than two (2) wire diameters or 1/8 inch (0.125) under the insulation. Contour of wire not visible at end of insulation. Insulation melted or damaged.

## BROKEN/DAMAGED STRANDS

*General*

Wire with broken, nicked, scraped, stretched, or cut strands *not* exceeding the numbers shown in Table 7.1 are acceptable.

*NOTE:* Minor scrapes shall be defined as the removal of plating or copper from strands in a longitudinal direction, which removes less than 25% of the cross section of the strand. Minor scrapes are permissible on 10%, maximum, of the strands.

TABLE 7.1

| STRANDS IN CONDUCTOR | PERMISSIBLE BROKEN/WICKED STRANDS |
|---|---|
| 0 – 6 | 0 |
| 7 – 16 | 1 |
| 17 – 26 | 2 |
| 27 – 36 | 3 |
| 37 – 46 | 4 |
| 47 and up | 10% of Total |
| Shield Strands only | Maximum of 10% of Total |

LOOSE STRANDS

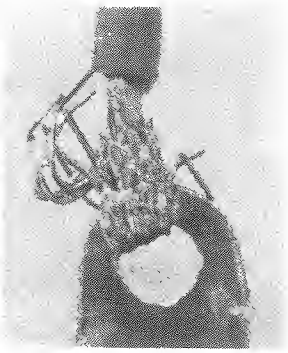
*General*

Any wire strand or strands extending outside the solder termination are unacceptable.

ACCEPTABLE (Preferred)
All wire strands are in the termination.

(BLANK)

ACCEPTABLE (Minimum)
There are no minimum acceptable conditions for loose strands.



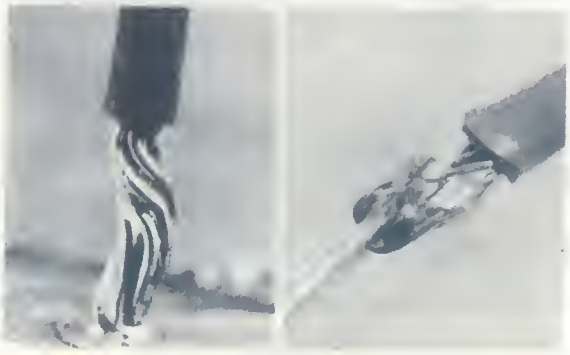
UNACCEPTABLE
Wire strands extending outside the solder termination.

BIRDCAGED WIRES

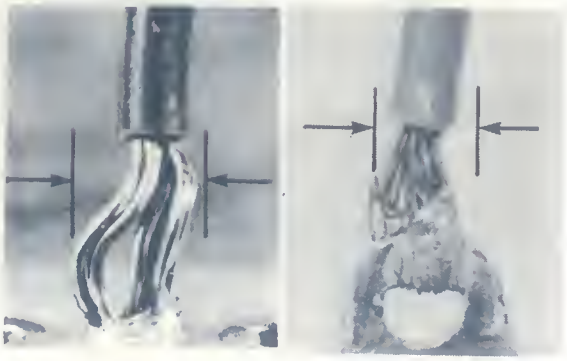
*General*

The disarrangement of the lay of wire usually due to reverse twisting is permissible only as long as it does not exceed the outside diameter of the wire's insulation.

ACCEPTABLE (Preferred)
Wires without birdcaging.



ACCEPTABLE (Minimum)
Birdcaging with strand disarranged to equal the outside diameter of the wire's insulation.



UNACCEPTABLE
Birdcaging with strand disarranged greater than the outside diameter of the wire's insulations.

## CRIMP TERMINALS

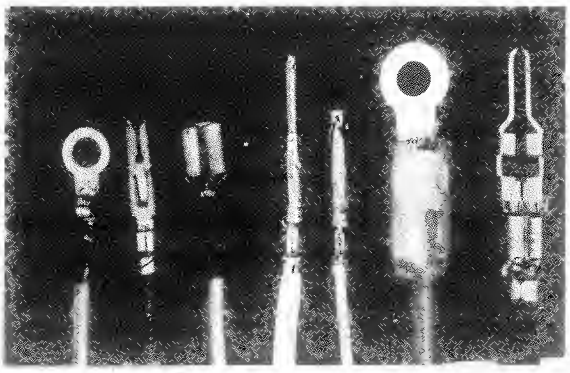
*Attachment of Terminal Lugs to Wire*

Terminal lugs attached to wires, as specified on engineering specifications or drawing, shall conform to the following requirements:

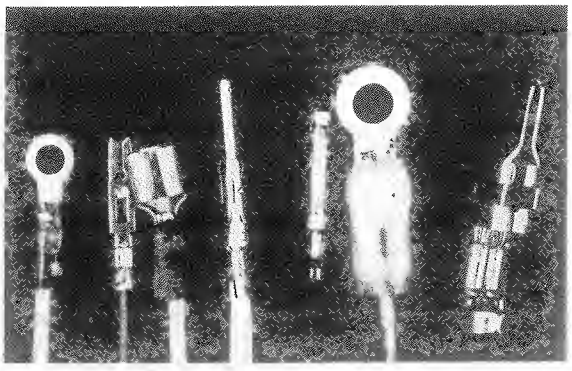
(a) The wire connector shall make contact with the entire length of the crimp barrel of the terminal.

(b) No loose strands shall be outside the connection after crimping.

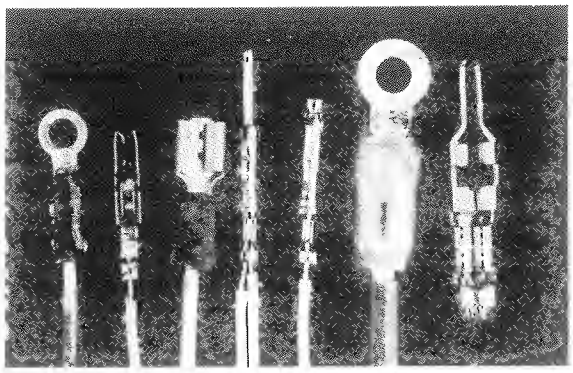
(c) There shall be no wire insulation under the conductor crimp barrel.



ACCEPTABLE
Wire and insulation are properly terminated within the prescribed limits.



UNACCEPTABLE
Wire insulation is in the crimp barrel.



UNACCEPTABLE
Wire insulation not in insulation barrel.

INSULATION SUPPORT

*General*

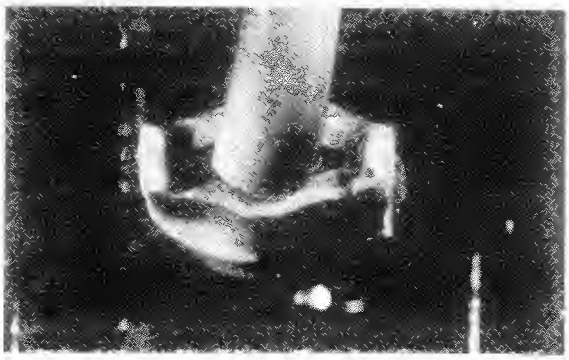
Where terminals with wire-insulation-support crimps are used, the insulation-support crimp shall support the wire insulation for the total length of the crimp.

After crimping, the end of the insulation, and wire shall be visible but not necessarily centered in their respective inspection window.

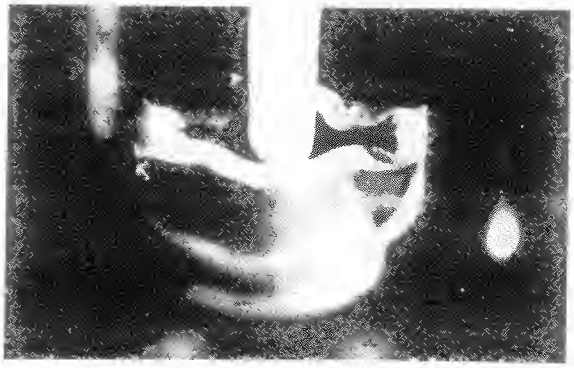
Insulation support barrels shall closely grip the insulation without crushing it.

The insulation shall remain in its original position on the barrel of the terminal or connector splice before and after crimping.

The insulation shall withstand a minimum axial force of six (6) pounds in either direction and shall not move in either direction more than 1/16 inch in the barrel of lug terminal or conductor splice.



ACCEPTABLE (Preferred)
Insulation support barrel snugly gripping insulation without crushing.



ACCEPTABLE (Minimum)
Insulation support barrel with slight openings on edge.

UNACCEPTABLE
Insulation support barrel improperly crimped, wire is not gripped snugly.

TENSILE TEST

*General*

The mechanical connection produced by attachment of terminal lugs to wire shall be capable of meeting the minimum tensile test values specified in Table 7.2.

*Splice*

Attachment: The conductor shall be bottomed against the wire stops in the splice. There shall be no insulation strip-gap beyond the point where the wire enters the splice connector.

TABLE 7.2

| WIRE GUAGE | TENSILE STRENGTH (POUNDS MINIMUM) | LUG COLOR |
|---|---|---|
| 22 | 15 | Red |
| 20 | 24 | Red |
| 18 | 35 | Red |
| 16 | 45 | Blue |
| 14 | 60 | Blue |
| 12 | 70 | Yellow |
| 10 | 80 | Yellow |

## WIRE COMBINATIONS IN LUGS

*General*

Wires in various combinations are allowed to be terminated in a given lug size. Table 7.3 gives the acceptable combinations.

TABLE 7.3

| LUG COLOR | WIRE GAUGE | ACCEPTABLE COMBINATIONS |
|---|---|---|
| Red | 18 | One (1) 18 Gauge Wire |
| | 20 | One (1) 20 Gauge Wire |
| | 22 | One (1) 22 Gauge Wire and One (1) 20 Gauge Wire |
| | | Three (3) 22 Gauge Wires |
| Blue | 14 | One (1) 14 Gauge Wire |
| | 16 | One (1) 16 Gauge Wire |
| | | Two (2) 18 Gauge Wires |
| | | One (1) 20 Gauge Wire and One (1) 18 Gauge Wire |
| | | Three (3) 20 Gauge Wires |
| | | Two (2) 22 Gauge Wires and Two (2) 20 Gauge Wires |
| | | Four (4) 22 Gauge Wires |
| Yellow | 10 | One (1) 10 Gauge Wire |
| | 12 | One (1) 12 Gauge Wire |
| | | One (1) 14 Gauge Wire and One (1) 12 Gauge Wire |
| | | Two (2) 16 Gauge Wires and Two (2) 14 Gauge Wires |
| | | Two (2) 18 Gauge Wires and Two (2) 16 Gauge Wires |
| | | Three (3) 18 Gauge Wires and One (1) 16 Gauge Wire |
| | | Four (4) 18 Gauge Wires |

GENERAL CRITERION TO DETERMINE ACCEPTABILITY

The following are characteristics of acceptable crimp terminals:

(a) No cracks around the crimp areas.
(b) Inspection hole not deformed to the extent that precludes its intended use.
(c) Wire strands visible through inspection hole in contact (where applicable).
(d) No wire insulation under the conductor crimp portion of the crimp barrel.
(e) Combined wire gage does not exceed recommended crimp barrel size. (see Table 7.3)
(f) Wire conductor makes contact with entire length of conductor crimp barrel.

*NOTE:* Rework of an unacceptable condition is not permitted. Flattened, split insulation or damaged terminal can only be repaired by cutting off the unacceptable termination and reterminating.

GENERAL CRITERION TO DETERMINE UNACCEPTABILITY

Any evidence of the following conditions shall be cause to classify the termination unacceptable:

(a) Indent not centered on terminal lug or splice causing damage/distortion.
(b) Insulation in conductor crimp barrel.
(c) Insulation not in insulation crimp of barrel.
(d) Wire extends beyond 3/32 (0.094) inch from the end of crimp barrel.
(e) Wire is not at least flush with the end of crimp barrel.
(f) Terminal is distorted.
(g) Wire strands outside of crimp.
(h) Cut or pinched insulation with inner conductor showing through.
(i) Over crimped terminal, distorted.
(j) Under crimped terminal (loose).
(k) Broken wires exceeding Table 7.1 requirements. (see page 7-1)
(l) Wrong terminal.
(m) Not meeting pull test requirements of Table 7.2. (see page 7-15)

## RETROFIT/REWORK/REPAIR PROCEDURES REFERENCES

*NOTE:* Refer to Engineering Specification A-SP-7665000-0-0 (Format and Index Spec.) for specific information.

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8.0 – TECHNICAL DATA

## PURPOSE

The purpose of this section (8.0) is to provide a variety of useful information of a very general nature.

## POLARITY RECOGNITION

Correct identification of component polarity is of the utmost importance. If a component is installed with the polarity reversed, serious damage will result to the component and the surrounding circuitry. Examples of polarity recognition are given in Figure 8-1. Consult your supervisor if there is any doubt to whether or not a component is polarized.

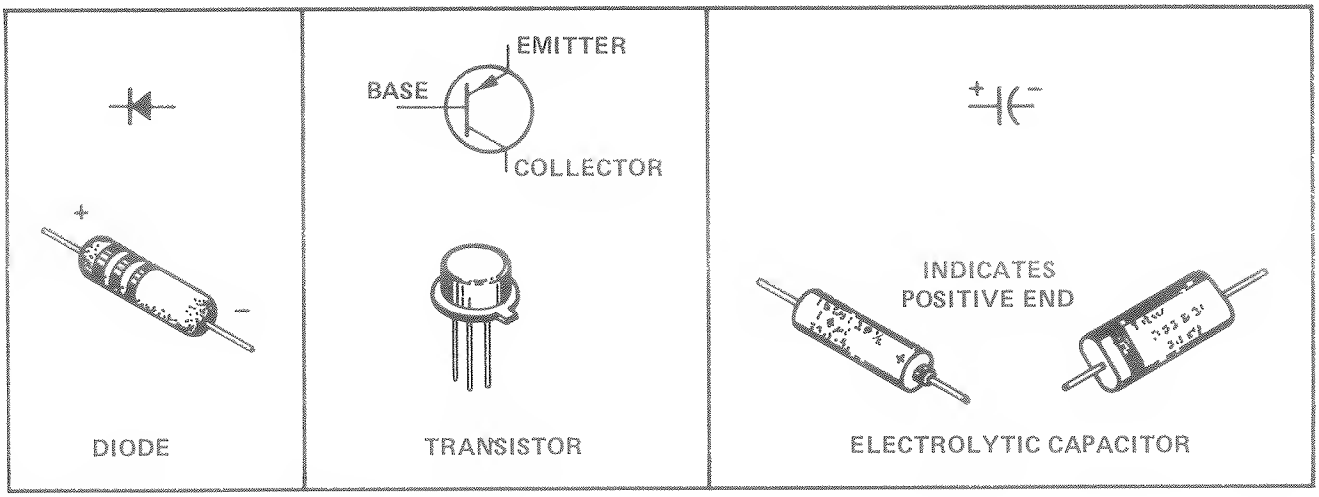
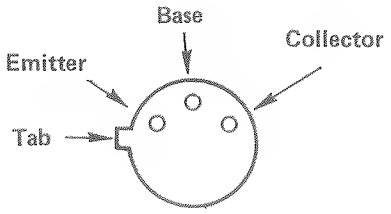



Figure 8-1.

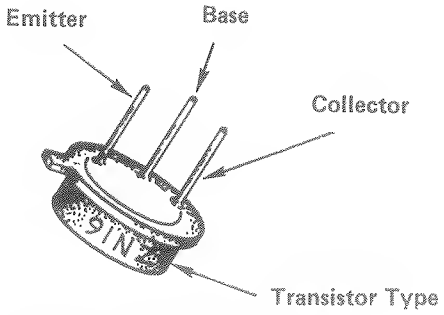
## TRANSISTOR AND DIODE IDENTIFICATION

Many types of transistors and diodes are in common use. The most common type of both transistors and diodes are shown along with their identification systems in diagram below.

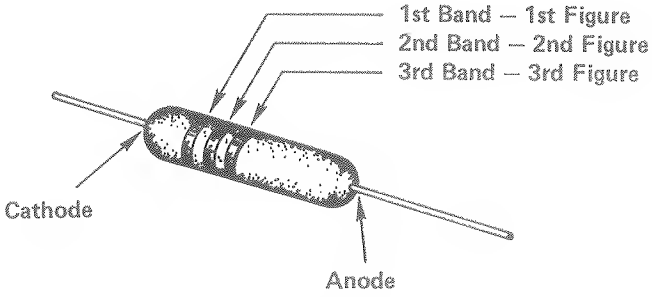
With the exception of the tolerance, diodes use the same color coding methods as do resistors. Diodes do not have a tolerance band.



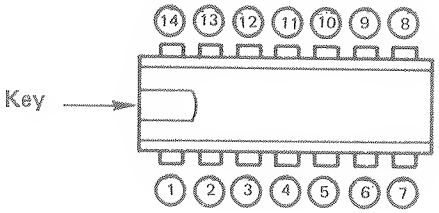

The tab is used to locate the leads of a transistor and is always to the left of the Emitter.




Transistor type is printed on side or top of transistor.




DIODE COLOR CODING
(Refer to page 8-3 for color code)

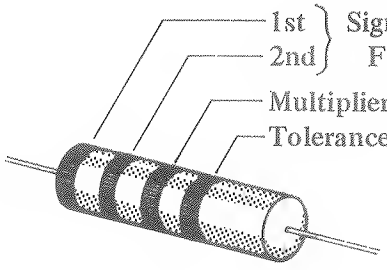



DUAL–IN–LINE PACKAGE (DIP)
(TOP VIEW – PINS POINTING AWAY)

RESISTOR CODES (Resistance Given in OHMS)

| COLOR | DIGIT | MULTIPLIER | TOLERANCE |
|---|---|---|---|
| Black | 0 | 1 | ±20% |
| Brown | 1 | 10 | ±1% |
| Red | 2 | 100 | ±2% |
| Orange | 3 | 1000 | ±3%* |
| Yellow | 4 | 10000 | GMV* |
| Green | 5 | 100000 | ±5% (EIA Alternate) |
| Blue | 6 | 1000000 | ±6%* |
| Violet | 7 | 10000000 | ±12½* |
| Gray | 8 | .01 (EIA Alternate) | ±30%* |
| White | 9 | .1 (EIA Alternate) | ±10% (EIA Alternate) |
| Gold | | .1 (JAN and EIA Preferred) | ±5% (JAN and EIA Preferred) |
| Silver | | .01 (JAN and EIA Preferred) | ±10% (JAN and EIA Preferred) |
| No Color | | | ±20% |

*GMV = guaranteed minimum value, or -0 + 100% tolerance. ±3, 6, 12½, and 30% are ASA 40, 20, 10, and 5 step tolerances.




Resistors With Black Body Color Are Composition, Non-Insulated.
Resistors With Colored Bodies Are Composition, Insulated.
Wire-Wound Resistors Have The 1st Digit Color Band Double Width.

BAND SYSTEM

| INCHES TO MILLIMETERS | | | | | |
|---|---|---|---|---|---|
| Inches | | MM | Inches | | MM |
| 1/64 | .016 | 0.397 | 33/64 | .516 | 13.097 |
| 1/32 | .031 | 0.794 | 17/32 | .531 | 13.493 |
| 3/64 | .047 | 1.191 | 35/64 | .547 | 13.891 |
| 1/16 | .063 | 1.588 | 9/16 | .563 | 14.288 |
| 5/64 | .078 | 1.984 | 37/64 | .578 | 14.684 |
| 3/32 | .094 | 2.381 | 19/32 | .594 | 15.081 |
| 7/64 | .109 | 2.778 | 39/64 | .609 | 15.478 |
| 1/8 | .125 | 3.175 | 5/8 | .625 | 15.875 |
| 9/64 | .141 | 3.572 | 41/64 | .641 | 16.272 |
| 5/32 | .156 | 3.969 | 21/32 | .656 | 16.669 |
| 11/64 | .172 | 4.366 | 43/64 | .672 | 17.066 |
| 3/16 | .188 | 4.763 | 11/16 | .688 | 17.463 |
| 13/64 | .203 | 5.159 | 45/64 | .703 | 17.859 |
| 7/32 | .219 | 5.556 | 23/32 | .719 | 18.256 |
| 15/64 | .234 | 5.953 | 47/64 | .734 | 18.653 |
| 1/4 | .250 | 6.350 | 3/4 | .750 | 19.050 |
| 17/64 | .266 | 6.747 | 49/64 | .766 | 19.447 |
| 9/32 | .281 | 7.144 | 25/32 | .781 | 19.844 |
| 19/64 | .297 | 7.541 | 51/64 | .797 | 20.241 |
| 5/16 | .313 | 7.938 | 13/16 | .813 | 20.638 |
| 21/64 | .328 | 8,334 | 53/64 | .828 | 21.034 |
| 11/32 | .344 | 8.731 | 27/32 | .844 | 21.431 |
| 22/64 | .359 | 9.128 | 55/64 | .859 | 21.828 |
| 3/8 | .375 | 9.525 | 7/8 | .875 | 22.225 |
| 25/64 | .391 | 9.922 | 57/64 | .891 | 22.622 |
| 13/32 | .406 | 10.319 | 29/32 | .906 | 23.019 |
| 27/64 | .422 | 10.716 | 59/64 | .922 | 23.416 |
| 7/16 | .438 | 11.113 | 15/16 | .938 | 23.813 |
| 29/64 | .453 | 11.509 | 61/64 | .953 | 24.209 |
| 15/32 | .469 | 11.906 | 31/32 | .969 | 24.606 |
| 31/64 | .484 | 12.303 | 63/64 | .984 | 25.003 |
| 1/2 | .500 | 12.700 | 1 | 1.000 | 25.400 |

| MILLIMETERS TO INCHES | | | | | | | |
|---|---|---|---|---|---|---|---|
| MM | Inches | MM | Inches | MM | Inches | MM | Inches |
| 1 | 0.0394 | 26 | 1.0235 | 51 | 2.0079 | 76 | 2.9921 |
| 2 | 0.0787 | 27 | 1.0630 | 52 | 2.0472 | 77 | 3.0315 |
| 3 | 0.1181 | 28 | 1.1024 | 53 | 2.0866 | 78 | 3.0709 |
| 4 | 0.1575 | 29 | 1.1417 | 54 | 2.1260 | 79 | 3.1102 |
| 5 | 0.1969 | 30 | 1.1811 | 55 | 2.1654 | 80 | 3.1496 |
| 6 | 0.2362 | 31 | 1.2205 | 56 | 2.2047 | 81 | 3.1890 |
| 7 | 0.2756 | 32 | 1.2598 | 57 | 2.2441 | 82 | 3.2284 |
| 8 | 0.3150 | 33 | 1.2992 | 58 | 2.2835 | 83 | 3.2677 |
| 9 | 0.3543 | 34 | 1.3386 | 59 | 2.3228 | 84 | 3.3071 |
| 10 | 0.3937 | 35 | 1.3780 | 60 | 2.3622 | 85 | 3.3465 |
| 11 | 0.4331 | 36 | 1.4173 | 61 | 2.4016 | 86 | 3.3858 |
| 12 | 0.4724 | 37 | 1.4567 | 62 | 2.4409 | 87 | 3.4252 |
| 13 | 0.5118 | 38 | 1.4961 | 63 | 2.4803 | 88 | 3.4646 |
| 14 | 0.5512 | 39 | 1.5354 | 64 | 2.5197 | 89 | 3.5039 |
| 15 | 0.5906 | 40 | 1.5748 | 65 | 2.5591 | 90 | 3.5433 |
| 16 | 0.6299 | 41 | 1.6142 | 66 | 2.5984 | 91 | 3.5827 |
| 17 | 0.6693 | 42 | 1.6535 | 67 | 2.6378 | 92 | 3.6221 |
| 18 | 0.7087 | 43 | 1.6929 | 68 | 2.6772 | 93 | 3.6614 |
| 19 | 0.7480 | 44 | 1.7323 | 69 | 2.7165 | 94 | 3.7008 |
| 20 | 0.7874 | 45 | 1.7717 | 70 | 2.7559 | 95 | 3.7402 |
| 21 | 0.8268 | 46 | 1.8110 | 71 | 2.7953 | 96 | 3.7795 |
| 22 | 0.8661 | 47 | 1.8504 | 72 | 2.8347 | 97 | 3.8189 |
| 23 | 0.9055 | 48 | 1.8898 | 73 | 2.8740 | 98 | 3.8583 |
| 24 | 0.9449 | 49 | 1.9291 | 74 | 2.9134 | 99 | 3.8976 |
| 25 | 0.9843 | 50 | 1.9685 | 75 | 2.9528 | 100 | 3.9370 |

| CENTIGRADE/FAHRENHEIT | | | | | | | |
|---|---|---|---|---|---|---|---|
| °C | °F | °C | °F | °C | °F | °C | °F |
| -80 | -112.0 | 15 | 59.0 | 75 | 167.0 | 135 | 275.0 |
| -70 | -94.0 | 16 | 60.8 | 76 | 168.8 | 136 | 276.8 |
| -60 | -65.0 | 18 | 64.4 | 78 | 172.4 | 138 | 280.4 |
| -50 | -58.0 | 20 | 68.0 | 80 | 176.0 | 140 | 284.0 |
| -40 | -40.0 | 21 | 69.8 | 81 | 177.8 | 141 | 285.8 |
| -38 | -36.4 | 22 | 71.6 | 82 | 179.6 | 142 | 287.6 |
| -36 | -32.8 | 24 | 75.2 | 84 | 183.2 | 144 | 291.2 |
| -35 | -31.0 | 25 | 77.0 | 85 | 185 | 145 | 293.0 |
| -33 | -27.4 | 27 | 80.6 | 87 | 188.6 | 147 | 296.6 |
| -32 | -25.6 | 28 | 82.4 | 88 | 189.4 | 148 | 298.4 |
| -30 | -22.0 | 30 | 86.0 | 90 | 194.0 | 150 | 302.0 |
| -29 | -20.2 | 31 | 87.8 | 91 | 195.8 | 160 | 320.0 |
| -27 | -16.6 | 33 | 91.4 | 93 | 199.4 | 180 | 356.0 |
| -26 | -14.8 | 34 | 93.2 | 94 | 201.2 | 190 | 374.0 |
| -24 | -11.2 | 36 | 96.8 | 96 | 204.8 | 200 | 392.0 |
| -23 | -9.4 | 37 | 98.6 | 97 | 206.6 | 210 | 410.0 |
| -21 | -5.8 | 39 | 102.2 | 99 | 210.2 | 230 | 446.0 |
| -20 | -4.0 | 40 | 104.0 | 100 | 212.0 | 250 | 482.0 |
| -18 | -0.4 | 42 | 107.6 | 102 | 215.6 | 300 | 572.0 |
| -17 | 1.4 | 43 | 109.4 | 103 | 217.4 | 400 | 752.0 |
| -15 | 5.0 | 45 | 113.0 | 105 | 221.0 | 500 | 932.0 |
| -14 | 6.8 | 46 | 114.8 | 106 | 222.8 | 600 | 1112.0 |
| -12 | 10.4 | 48 | 118.4 | 108 | 226.4 | 700 | 1292.0 |
| -10 | 14.0 | 50 | 122.0 | 110 | 230.0 | 800 | 1472.0 |
| -9 | 15.8 | 51 | 123.8 | 111 | 231.8 | 900 | 1652.0 |
| -8 | 17.6 | 52 | 125.6 | 112 | 233.6 | 1000 | 1832.0 |
| -6 | 21.2 | 54 | 129.2 | 114 | 237.2 | 1200 | 2192.0 |
| -5 | 23.0 | 55 | 131.0 | 115 | 239.0 | 1400 | 2552.0 |
| -3 | 26.6 | 57 | 134.6 | 117 | 242.6 | 1700 | 3092.0 |
| -2 | 28.4 | 58 | 136.4 | 118 | 244.4 | 2000 | 3632.0 |
| 0 | 32.0 | 60 | 140.0 | 120 | 248.0 | | |
| 1 | 33.8 | 61 | 141.8 | 121 | 249.8 | | |
| 3 | 37.4 | 63 | 145.4 | 123 | 253.4 | | |
| 4 | 39.2 | 64 | 147.2 | 124 | 255.2 | | |
| 6 | 42.8 | 66 | 150.8 | 126 | 258.8 | | |
| 7 | 44.6 | 67 | 152.6 | 127 | 260.6 | | |
| 9 | 48.2 | 69 | 156.2 | 129 | 264.2 | | |
| 10 | 50.0 | 70 | 158.0 | 130 | 266.0 | | |
| 12 | 53.6 | 72 | 161.6 | 132 | 269.6 | | |
| 13 | 55.4 | 73 | 163.4 | 133 | 271.4 | | |

FORMULA
DEGREE C = 5/9 (F–32)
DEGREE F = 32 + 9/5C

| AMERICAN WIRE GAUGE/INCHES/MILLIMETERS | | | | | |
|---|---|---|---|---|---|
| AWG | Inches | MM | AWG | Inches | MM |
| 48 | .00124 | .03149 | 29 | .0113 | .28702 |
| 47 | .00140 | .03556 | 28 | .0126 | .32004 |
| 46 | .00157 | .03987 | 27 | .0142 | .36068 |
| 45 | .00176 | .04470 | 26 | .0159 | .40386 |
| 44 | .0020 | .05080 | 25 | .0179 | .45466 |
| 43 | .0022 | .05588 | 24 | .0201 | .51054 |
| 42 | .0025 | .06350 | 23 | .0226 | .57404 |
| 41 | .0028 | .07112 | 22 | .0253 | .64262 |
| 40 | .0031 | .07874 | 21 | .0285 | .72390 |
| 39 | .0035 | .08890 | 20 | .0320 | .81280 |
| 38 | .0040 | .10160 | 19 | .0359 | .91186 |
| 37 | .0045 | .11430 | 18 | .0403 | 1.0236 |
| 36 | .0050 | .12700 | 17 | .0453 | 1.1506 |
| 35 | .0056 | .14224 | 16 | .0508 | 1.2903 |
| 34 | .0063 | .16002 | 15 | .0571 | 1.4503 |
| 33 | .0071 | .18034 | 14 | .0641 | 1.6281 |
| 32 | .0080 | .20320 | 13 | .0720 | 1.8288 |
| 31 | .0089 | .22606 | 12 | .0808 | 2.0523 |
| 30 | .0100 | .25400 | | | |

| PREFIXES USED IN THE METRIC SYSTEM | | | | | |
|---|---|---|---|---|---|
| T | tera | = | $10^{12}$ | = | 1,000,000,000,000 |
| G | giga | = | $10^{9}$ | = | 1,000,000,000 |
| M | mega | = | $10^{6}$ | = | 1,000,000 |
| k | kilo | = | $10^{3}$ | = | 1,000 |
| h | hecto | = | $10^{2}$ | = | 100 |
| da | deca | = | $10^{1}$ | = | 10 |
| d | deci | = | $10^{-1}$ | = | 0.1 |
| c | centi | = | $10^{-2}$ | = | 0.01 |
| m | milli | = | $10^{-3}$ | = | 0.001 |
| $\mu$ | micro | = | $10^{-6}$ | = | 0.000.001 |
| n | nano | = | $10^{-9}$ | = | 0.000.000.001 |
| p | pico | = | $10^{-12}$ | = | 0.000.000.000.001 |
| f | femto | = | $10^{-15}$ | = | 0.000.000.000.000.001 |
| a | atto | = | $10^{-18}$ | = | 0.000.000.000.000.000.001 |

e.g., 1 GW (gigawatt) = $10^{9}$ W = $10^{6}$ kW = $10^{3}$ MW

| MATHEMATICAL CONSTANTS | | | | | |
|---|---|---|---|---|---|
| Symbol | Number ($\eta$) | lg $\eta$ | Symbol | Number ($\eta$) | lg $\eta$ |
| $\sqrt{2}$ | 1.41421 | 0.15052 | $4\pi^2$ | 39.47842 | 1.59636 |
| $\sqrt{3}$ | 1.73205 | 0.23856 | $\pi^2/4$ | 2.46740 | 0.39224 |
| $\pi$ | 3.14159 | 0.49715 | $\pi\sqrt{2}$ | 4.44288 | 0.64766 |
| $4\pi$ | 12.56637 | 1.09921 | $\pi/\sqrt{2}$ | 2.22144 | 0.34663 |
| $\pi/2$ | 1.57080 | 0.19612 | e | 2.71828 | 0.43429 |
| $\pi/3$ | 1.04720 | 0.02003 | $e^2$ | 7.38906 | 0.86859 |
| $\pi/4$ | 0.78540 | 0.89509-1 | 1/e | 0.36788 | 0.56571-1 |
| $1/\pi$ | 0.31831 | 0.50285-1 | ln 2 | 0.69315 | 0.84083-1 |
| $180/\pi$ | 57.29578 | 1.75812 | ln 10 | 2.30259 | 0.36222 |
| $1/\sqrt{\pi}$ | 0.56419 | 0.75143-1 | $M_{10^1}$ | 0.43429 | 0.63778-1 |
| $\pi^2$ | 9.86960 | 0.99430 | $1/M_{10}$ | 2.30259 | 0.36222 |

| ROMAN NUMERALS | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | II | III | IV | V | VI | VII | VIII | IX | X | XI | XX | XXX |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 20 | 30 |
| | | | XL | L | LX | LXX | LXXX | XC | C | D | M | |
| | | | 40 | 50 | 60 | 70 | 80 | 90 | 100 | 500 | 1,000 | |
| | | | | | | MDCCCXLVII | | MCMLXIX | | | | |
| | | | | | | 1847 | | 1969 | | | | |

| GREEK ALPHABET | | | | | | | |
|---|---|---|---|---|---|---|---|
| Α α | Β β | Γ γ | Δ δ | Ε ε | Ζ ζ | Η η | Θ θ |
| alpha | beta | gamma | delta | epsilon | zeta | eta | theta |
| Ι ι | Κ κ | Λ λ | Μ μ | Ν ν | Ξ ξ | Ο ο | Π π |
| iota | kappa | lambda | mu | nu | xi | omicron | pi |
| Ρ ρ | Σ σ | Τ τ | Υ υ | Φ φ | Χ χ | Ψ ψ | Ω ω |
| rho | sigma | tau | ypsilon | phi | chi | psi | omega |

## BINARY NUMBERS

| | 16 | 8 | 4 | 2 | 1 |
|---|---|---|---|---|---|
| 0 | | | | | 0 |
| 1 | | | | | 1 |
| 2 | | | | 1 | 0 |
| 3 | | | | 1 | 1 |
| 4 | | | 1 | 0 | 0 |
| 5 | | | 1 | 0 | 1 |
| 6 | | | 1 | 1 | 0 |
| 7 | | | 1 | 1 | 1 |
| 8 | | 1 | 0 | 0 | 0 |
| 9 | | 1 | 0 | 0 | 1 |
| 10 | | 1 | 0 | 1 | 0 |

| | 16 | 8 | 4 | 2 | 1 |
|---|---|---|---|---|---|
| 11 | | 1 | 0 | 1 | 1 |
| 12 | | 1 | 1 | 0 | 0 |
| 13 | | 1 | 1 | 0 | 1 |
| 14 | | 1 | 1 | 1 | 0 |
| 15 | | 1 | 1 | 1 | 1 |
| 16 | 1 | 0 | 0 | 0 | 0 |
| 17 | 1 | 0 | 0 | 0 | 1 |
| 18 | 1 | 0 | 0 | 1 | 0 |
| 19 | 1 | 0 | 0 | 1 | 1 |
| 20 | 1 | 0 | 1 | 0 | 0 |
| 21 | 1 | 0 | 1 | 0 | 1 |

| | 16 | 8 | 4 | 2 | 1 |
|---|---|---|---|---|---|
| 22 | 1 | 0 | 1 | 1 | 0 |
| 23 | 1 | 0 | 1 | 1 | 1 |
| 24 | 1 | 1 | 0 | 0 | 0 |
| 25 | 1 | 1 | 0 | 0 | 1 |
| 26 | 1 | 1 | 0 | 1 | 0 |
| 27 | 1 | 1 | 0 | 1 | 1 |
| 28 | 1 | 1 | 1 | 0 | 0 |
| 29 | 1 | 1 | 1 | 0 | 1 |
| 30 | 1 | 1 | 1 | 1 | 0 |
| 31 | 1 | 1 | 1 | 1 | 1 |

## DECIMAL TO BINARY CONVERSION RULES

(a) Write number n + 0 if even or (n - 1) + 1 if odd.

(b) Divide even number obtained in (a) by 2.
Write answer (m) below in same form:

m + 0 if even, (m - 1) + 1 if odd.

(c) Continue until m or (m - 1) becomes zero.

(d) Column of ones and zeros so obtained is binary equivalent of n with least significant digit at the top.

*EXAMPLE:* n = 327

326 + 1
162 + 1
80 + 1
40 + 0
20 + 0
10 + 0
4 + 1
2 + 0
0 + 1

Therefore the binary equivalent of 327 is 101000111

## BINARY TO DECIMAL CONVERSION RULES

(a) Start at left with first significant digit – double it if the next digit is a zero or "dibble" it (double and add one) if the next digit is a one.

(b) If the third digit is a zero, double value obtained in (a), if it is a one "dibble" value obtained in (a).

(c) Continue until operation indicated by least significant digit has been performed.

| MATH SYMBOLS | |
|---|---|
| × or : | Multiplied by |
| ÷ or : | Divided by |
| + | Positive. Plus. Addition |
| − | Negative. Minus. Subtraction |
| ± | Positive or negative. Plus or minus |
| ∓ | Negative or positive. Minus or plus |
| = or : : | Equals |
| ≡ | Identify |
| ≅ | Is approximately equal to |
| ≠ | Does not equal |
| > | Is greater than |
| ⩾ | Is much greater than |
| < | Is less than |
| ⩽ | Is much less than |
| ⩾ | Greater than or equal to |
| ⩽ | Less than or equal to |
| ∴ | Therefore |
| ∠ | Angle |
| ∠s | Angles |
| △ | Change. Increase or decrease |
| ⊥ | Perpendicular to |
| ∥ | Parallel to |
| $\lvert n \rvert$ | Absolute value of $n$ |
| $\sqrt{\ }$ | Square root |
| $\sqrt[3]{\ }$ | Cube root |

| Terms of Numbers | | | |
|---|---|---|---|
| Unit | Symbol | Multiple | Value |
| volt | E | kilovolt (kv) | 1,000 volts |
| volt | E | millivolt (mv) | 1/1,000 volt |
| volt | E | microvolt ($\mu$v) | 1/1,000,000 volt |
| ohm | R | kilohm | 1,000 ohms |
| ohm | R | megohm | 1,000,000 ohms |
| ampere | I | milliampere (ma) | 1/1,000 ampere |
| ampere | I | microampere ($\mu$a) | 1/1,000,000 ampere |

| In Terms of Exponents | | |
|---|---|---|
| 1 volt | = $10^{3}$ millivolts | = $10^{6}$ microvolts |
| 1 millivolt | = $10^{-3}$ volt | = $10^{3}$ microvolts |
| 1 microvolt | = $10^{-6}$ volt | = $10^{-3}$ millivolt |
| 1 ohm | = $10^{-3}$ kilohm | = $10^{-6}$ megohm |
| 1 kilohm | = $10^{3}$ ohms | = $10^{-3}$ megohm |
| 1 megohm | = $10^{6}$ ohms | = $10^{3}$ kilohms |
| 1 ampere | = $10^{3}$ milliamperes | = $10^{6}$ microamperes |
| 1 milliampere | = $10^{-3}$ ampere | = $10^{3}$ microamperes |
| 1 microampere | = $10^{-6}$ ampere | = $10^{-3}$ milliamperes |

| Comparison of electric and magnetic circuits. | | |
|---|---|---|
| | Electric Circuit | Magnetic Circuit |
| Force | Volt, E, or e.m.f. | Gilberts, F, or m.m.f. |
| Flow | Ampere, I | Flux, $\Phi$, in maxwells |
| Opposition | Ohms, R | Reluctance, R, or rels |
| Law | Ohm's law, I = E/R | Rowland's law, $\Phi$ = F/R |
| Intensity of force | Volts per cm. of length | H = 1.257IN/I, gilberts per centimeter of length. |
| Density | Current density -- for example, amperes per cm.$^{2}$ | Flux density -- for example, lines per cm$^{2}$, or gausses. |

## OHM'S LAW

The two triangles shown in Figure 1 are memory aids for remembering Ohm's law. Cover the *unknown* value with a finger tip and the triangle automatically reveals the correct formula to use. If you want to find the current in a circuit (just as an example) cover the letter *I* or the word "amps" and the formula is revealed as either *E* divided by *R* or volts divided by ohms.

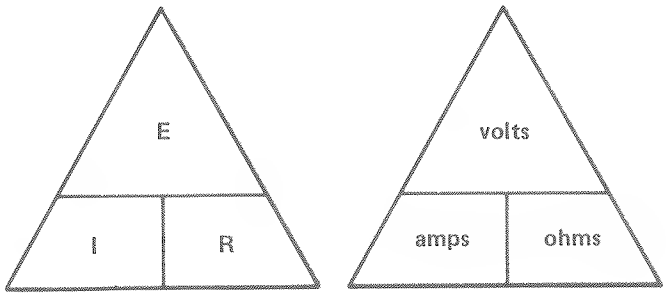



Figure 1. These are memory aids for remembering Ohm's law. Ohm's law is one of the most widely used formulas in electronics.

## POWER

The power in a dc circuit involves values of voltage, current and resistance. In the basic power formula (Figure 2):

$$P = E \times I$$

power *(P)* is in watts, voltage *(E)* is in volts and the current *(I)* is in amperes

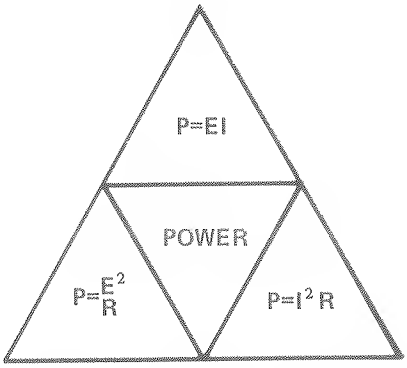



Figure 2. These are the three basic power laws. The power laws can be combined with Ohm's law to yield other useful formulas.

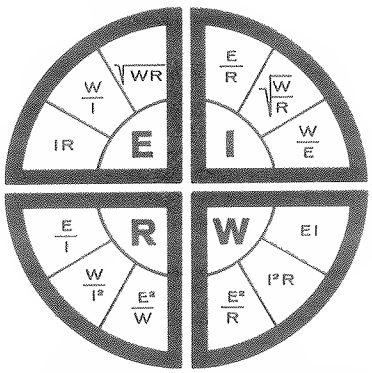



Figure 3. Reference Chart

## OCTAL-DECIMAL CONVERSION

The following table gives the multiples of the powers of 8. To convert a number from octal to decimal using the table, add the decimal number opposite the digit value for each digit position. To convert $40277_8$ to decimal, the following numbers are obtained from the table and added.

| Position | Digit | Table entry |
|---|---|---|
| 5 | 4 | 16384 |
| 4 | 0 | 0 |
| 3 | 2 | 128 |
| 2 | 7 | 56 |
| 1 | 7 | 7 |

$$16575_{10} = 40277_8$$

This process is reversed to convert a number from decimal to octal. Subtract out the largest table entry which allows a positive remainder, then take the column number (position coefficient) of the table entry as the Nth digit of the result, where *N* is the row number (digit position) of the table entry. Continue this process, operating on the remainder from each step in the next step, until all digits of the results have been found. For example, to convert $23365_{10}$ to an equivalent octal number:

$$\begin{array}{rl} 23365 & \\ -20480 = & 5 \times 8^4 \\ 2885 & \\ -2560 = & 5 \times 8^3 \\ 325 & \\ -320 = & 5 \times 8^2 \\ 5 & \\ -0 = & 0 \times 8^1 \\ 5 & \\ -5 = & 5 \times 8^0 \\ 0 & \end{array}$$

$$55505_8 = 23365_{10}$$

| Octal Digit Position/$8^n$ | Position Coefficients (Multipliers) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1st ($8^0$) | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 2nd ($8^1$) | 0 | 8 | 16 | 24 | 32 | 40 | 48 | 56 |
| 3rd ($8^2$) | 0 | 64 | 128 | 192 | 256 | 320 | 384 | 448 |
| 4th ($8^3$) | 0 | 512 | 1,024 | 1,536 | 2,048 | 2,560 | 3,072 | 3,584 |
| 5th ($8^4$) | 0 | 4,096 | 8,192 | 12,288 | 16,384 | 20,480 | 24,576 | 28,672 |
| 6th ($8^5$) | 0 | 32,768 | 65,536 | 98,304 | 131,072 | 163,840 | 196,608 | 229,376 |

## INFORMATION REQUEST

Your comments and suggestions will help us in our continual effort to improve the content and usefulness of this WORKMANSHIP MANUAL. Please take a few minutes, fill out this questionnaire and mail.

1. In general, were the copy and illustrations easy to understand? Yes ☐ No ☐

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   Comments _____

3. Did you feel any superfluous or unnecessary information was given? Yes ☐ No ☐

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5. It is planned to review this manual on an annual basis. What changes, if any, would you like to see made in the next edition?

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